DRAFT

ENVIRONMENTAL STATEMENT FOR THE PROPOSED PROTOTYPE OIL SHALE LEASING PROGRAM

DES-72-89

Volume I of III

Description of Regions and Potential Environmental Impacts

U.S. DEPARTMENT OF THE INTERIOR

SEPTEMBER 1972

DRAFT

ENVIRONMENTAL STATEMENT

FOR THE

PROPOSED PROTOTYPE OIL-SHALE LEASING PROGRAM

VOLUME I of III

Descriptions of the Regions
and
Potential Environmental Impacts

Prepared in Compliance with

Section 102 (2) (c) of the National Environmental

Policy Act of 1969

Prepared by

UNITED STATES DEPARTMENT OF THE INTERIOR

September 1972

SUMMARY

Draft Environmental Impact Statement
Department of the Interior, Office of the Secretary

1. Type of action: Administrative

2. Brief description of action:

   This proposed action would make available for private development up to six leases of not more than 5,120 acres each. Two tracts are located in each of the states of Colorado, Utah, and Wyoming.

   Such leases would be sold by competitive bonus bidding and would require the payment to the United States of royalty on production. Additional oil shale leasing would not be considered until development under the proposed program had been satisfactorily evaluated.

3. Summary of environmental impact and adverse environmental effects:

   Oil shale development would produce both direct and indirect changes in the environment of the oil shale region in each of the three states where commercial quantities of oil shale resources exist. Many of the environmental changes would be of local significance while others would be of an expanding nature and have cumulative impact. These major regional changes will conflict with other physical resources and uses of the land and water involved. Impacts would include those on the land itself, the water resources and air quality, on fish and wildlife habitat, on grazing and agricultural activities, on recreation and aesthetic values, and on the existing social and economic patterns as well as others. The environmental impacts from both prototype development and a mature industry are assessed for their anticipated direct, indirect, and cumulative effects.

4. Alternatives considered:

   A. Alternative Leasing Tracts.
   B. Alternative Oil Shale Leasing Policies.
   C. Alternative Energy Policies.
   D. Alternative Energy Sources.

5. Comments have been requested from the following: (see attached sheet).

6. Date made available to CEQ and the public:

   Draft Statement:

Comments Requested

Federal Agencies

Environmental Protection Agency
Department of Commerce
Department of Transportation
Atomic Energy Commission
Federal Power Commission
Office of Emergency Preparedness
Department of Defense - Office of Naval Petroleum and Oil Shale Reserves
Department of Agriculture
Bureau of Sport Fisheries and Wildlife, Department of the Interior
National Park Service, Department of the Interior
Bureau of Recreation, Department of the Interior
Geological Survey, Department of the Interior
Bureau of Mines, Department of the Interior
Office of Coal Research, Department of the Interior
Office of Oil and Gas, Department of the Interior
Bureau of Land Management, Department of the Interior
Bureau of Indian Affairs, Department of the Interior
Bureau of Reclamation, Department of the Interior

State House Agencies

Colorado Department of Local Affairs
Utah State Planning Coordinator
Wyoming State Planning Coordinator
Oil Shale Regional Planning Commission (of Garfield, Mesa and Rio Blanco Counties, Colorado)
County Commissioners of Utah County and Wyoming County

Private Organizations

Natural Resources Defense Council
Rocky Mountain Center on Environment
University of Wisconsin, Glen D. Weaver
Colorado Open Space Council
Sierra Club
Wilderness Society
National Audubon Society
National Recreation and Park Association
Wildlife Management Institute
National Wildlife Federation
Issac Walton League
Environmental Action
Friends of the Earth
Environmental Policy Center
Conservation Foundation
Nature Conservancy
American Forest Association
Center for Law and Social Policy
Environmental Defense Fund
Colorado Sportsmen's Association
Rocky Mountain Sportsmen's Federation
National Council of Public Land Users
Utah Wildlife Federation

Wyoming Open Space Council
American Petrofina of Texas
Ashland Oil, Inc.
Barodynamics, Inc.
Occidental Petroleum Corporation
Garrett Research (Occidental Petroleum Corporation)
Geokinetics, Inc.
Gulf Minerals Resources Company
Marathon Oil Company
The Oil Shale Corporation
Phelps Dodge Corporation
Shell Oil Company
SOHIO Petroleum Company
The Superior Oil Company
Cameron Engineers
Sun Oil Company
Western Oil Shale Corporation
Mobil Oil Company
Chevron Oil Company
Equity Oil Company
Cities Service Oil Company
Carter Oil Company
Union Oil Company
Getty Oil Company
Development Engineering
Denver Audubon Society
Thorn Ecological Institute
Colorado State Rehabilitation Sub-Committee
Denver Research Institute
Humble Oil and Refining Company
AMOCO Production Company
Bell Petroleum Company

INTRODUCTORY NOTE

THIS DRAFT ENVIRONMENTAL STATEMENT HAS BEEN PREPARED PURSUANT TO SECTION 102 (2) (C) OF THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969 (42 U.S.C. SECS. 4321-4347). ITS GENERAL PURPOSE IS A STUDY OF THE ENVIRONMENTAL IMPACTS OF OIL SHALE DEVELOPMENT.

THE SECRETARY OF THE INTERIOR ANNOUNCED PLANS ON JUNE 29, 1971, FOR THIS PROPOSED PROGRAM AND RELEASED A PRELIMINARY ENVIRONMENTAL STATEMENT, A PROGRAM STATEMENT, AND REPORTS PREPARED BY THE STATES OF COLORADO, UTAH, AND WYOMING ON THE ENVIRONMENTAL COSTS AND PROBLEMS OF OIL SHALE DEVELOPMENT.

THE PROPOSED PROGRAM IS IN CONCERT WITH THE PRESIDENT'S ENERGY MESSAGE OF JUNE 4, 1971, IN WHICH HE REQUESTED THAT THE SECRETARY OF THE INTERIOR INITIATE "A LEASING PROGRAM TO DEVELOP OUR VAST OIL SHALE RESOURCES, PROVIDED THAT ENVIRONMENTAL QUESTIONS CAN BE SATISFACTORILY RESOLVED."

AS PART OF THE PROGRAM, THE DEPARTMENT AUTHORIZED INFORMATIONAL CORE DRILLING AT VARIOUS SITES IN COLORADO AND UTAH AND 16 CORE HOLES WERE COMPLETED. THE DEPARTMENT REQUESTED NOMINATIONS OF PROPOSED LEASING TRACTS ON NOVEMBER 2, 1971, AND A TOTAL OF 20 INDIVIDUAL TRACTS OF OIL SHALE LAND WERE NOMINATED. WITH THE CONCURRENCE OF THE CONCERNED STATES, THE DEPARTMENT OF THE INTERIOR ANNOUNCED ON APRIL 25, 1972, THE SELECTION OF 6 OF THESE TRACTS, 2 EACH IN COLORADO, UTAH, AND WYOMING.

THE PROPOSED PROGRAM IS ESSENTIALLY UNCHANGED FROM THAT ANNOUNCED ON JUNE 29, 1971, BUT THE PRELIMINARY STATEMENT ISSUED AT THAT TIME HAS BEEN EXPANDED TO CONSIDER THE IMPACT OF A FULL-SCALE OIL SHALE INDUSTRY, THE IMPACT OF DEVELOPMENT OF THE SIX SPECIFIC TRACTS, AND A COMPREHENSIVE ANALYSIS OF OTHER ENERGY ALTERNATIVES. THIS INFORMATION IS NOW CONTAINED IN THREE VOLUMES.

THE FIRST VOLUME PROVIDES AN ASSESSMENT OF THE CURRENT STATE OF OIL SHALE TECHNOLOGY. VOLUME I ALSO DESCRIBES THE REGIONAL ENVIRONMENTAL IMPACT OF OIL SHALE DEVELOPMENT IN THE FORM OF PRODUCTION FROM PUBLIC AND PRIVATE LANDS, THE DEVELOPMENT OF WHICH MAY BE STIMULATED BY THE DEPARTMENT'S PROPOSED ACTION. VOLUME II EXTENDS THIS STUDY WITH AN EXAMINATION OF ALTERNATIVES TO SHALE OIL PRODUCTION AT THE RATE OF 1-MILLION BARRELS PER DAY BY 1985. VOLUMES I AND II THUS CONSIDER THE BROAD GENERAL AND CUMULATIVE ASPECTS OF OIL SHALE DEVELOPMENT.

VOLUME III EXAMINES THE SPECIFIC PROPOSED ACTION UNDER CONSIDERATION, WHICH IS THE ISSUANCE OF NOT MORE THAN TWO PROTOTYPE OIL SHALE LEASES IN EACH OF THE THREE STATES OF COLORADO, UTAH, AND WYOMING.

THIS DOCUMENT IS BASED ON MANY SOURCES OF INFORMATION, INCLUDING RESEARCH DATA AND PILOT PROGRAMS DEVELOPED BY BOTH THE GOVERNMENT AND PRIVATE INDUSTRY OVER THE PAST THIRTY YEARS. MANY FACTORS SUCH AS CHANGING TECHNOLOGY, EVENTUAL OIL PRODUCTION LEVELS, AND

ATTENDANT REGIONAL POPULATION INCREASES ARE NOT PRECISELY PREDICTABLE. THE IMPACT ANALYSIS INCLUDED HEREIN IS CONSIDERED TO CONSTITUTE A REASONABLE TREATMENT OF THE POTENTIAL ENVIRONMENTAL EFFECTS WHICH WOULD BE ASSOCIATED WITH OIL SHALE DEVELOPMENT. DEPARTMENTAL EXPERTS, IN THE MANY AREAS WHICH ARE DISCUSSED, HAVE USED THEIR BEST JUDGMENT TO FORECAST THESE ENVIRONMENTAL EFFECTS.

ANY WRITTEN COMMENTS ON THIS DRAFT STATEMENT RECEIVED WITHIN 45 DAYS OF THE ISSUANCE OF THIS STATEMENT WILL BE GIVEN CAREFUL CONSIDERATION. PUBLIC HEARINGS WILL BE SCHEDULED WITHIN THE SAME 45-DAY REVIEW PERIOD. UPON COMPLETION OF THE REVIEW PERIOD, THE DEPARTMENT WILL WEIGH ALL INFORMATION AND COMMENTS RECEIVED AND, IF THE DECISION IS TO PROCEED FURTHER, WILL PREPARE A FINAL ENVIRONMENTAL STATEMENT. ONLY AFTER COMPLETION OF THE FINAL ENVIRONMENTAL STATEMENT AND COMPLIANCE WITH ALL THE REQUIREMENTS OF NEPA AND THE COUNCIL ON ENVIRONMENTAL QUALITY GUIDLINES ISSUED PURSUANT TO IT, WILL A FINAL DECISION BE MADE WHETHER TO PROCEED WITH AN OIL SHALE LEASING PROGRAM.

AVAILABILITY OF DRAFT ENVIRONMENTAL STATEMENT

The three-volume set may be purchased by mail or in person from the Map Information Office, Geological Survey, U. S. Department of the Interior, Washington, D. C. 20240. The set is priced at $7.00. Individual volumes are $3.00 for Volume I, $1.00 for Volume II, and $3.00 for Volume III.

Copies may also be purchased from Bureau of Land Management State Offices in the following cities: Denver, Colo. (Colorado State Bank Building, 1600 Broadway, Denver, Colorado, 80202); Salt Lake City, Utah (Federal Building, 124 South State, Salt Lake City, Utah, 84111); and Cheyenne, Wyo. (Joseph C. O'Mahoney, Federal Center, 2120 Capital Avenue, Cheyenne, Wyoming, 82001). Inspection copies are available in the following Bureau of Land Management district offices: Colorado: Canon City, Craig, Glenwood Springs, Grand Junction, Montrose; Utah: Vernal, Price, Monticello, Kanab, Richfield; Wyoming: Rock Springs, Rawlins, Casper, Lander, Pinedale, Worland.

TABLE OF CONTENTS

Page

Page

Page

Page

Page

Page

Page

Page

LIST OF TABLES

Page

III. Environmental Impact

LIST OF ILLUSTRATIONS

Figure	III. Environmental Impact	Page

I. DESCRIPTION OF THE PROPOSED ACTION

A. Introduction

Oil shale is one of the Nation's most abundant energy resources. The richest deposits, located in the Rocky Mountain area of the country, represent billions of barrels of oil. Development of this resource has not been undertaken in the past because accessible supplies of oil and gas have been available at a lower developmemt cost. The Nation's future energy needs are so large, however, that it is anticipated that our conventional domestic oil and gas deposits will be suplemented by synthetic fuels derived from oil shale and other convertible fossil fuel sources within the next decade.

This document examines the regional environmental impact expected from shale development on private and public lands. A companion document (1)[1/] reviews the specific impacts associated with the development of six leases on public lands if the Department of the Interior's proposed prototype oil shale leasing program is implemented. This chapter provides a current state-of-the art assessment of the technology that may be employed in oil shale development. Included in this assessment are methods of processing; technology related to the management of solid wastes and wastes within the working areas; monitoring methods; and a guide to current research that pertains to the environmental aspects of oil shale development.

1/ Underlined Numbers in parenthesis refer to items in the list of references at the end of this chapter.

Subsequent chapters of this Volume describe the regional environmental impact of oil shale development to a maximum cumulative production of 1 million barrels per day by 1985. Alternatives to this scale of development are analyzed in Volume II.

B. Background

Large areas of the United States are known to contain oil shale deposits, but those areas in Colorado, Utah, and Wyoming that contain the organic-rich sedimentary rocks of the Green River Formation are of greatest promise for shale oil production in the immediate future (Figure I-1). The oil shale deposits occur beneath 25,000 square miles (16 million acres) of lands, of which about 17,00 square miles (11 million acres) are believed to contain oil shale of potential value for commercial development in the foreseeable future.

The known Green River Formation deposits include high-grade shales [1/] that represent about 600 billion barrels of oil.[2/] Recovery of even a small fraction of this resource would represent a significant

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1/ At least 10 feet thick and averaging 25 or more gallons per ton.

2/ An additional 1,200 billion barrels are present in place in lower-grade shales, in sequences more than 10 feet thick that have an average yield of 15 to 20 gallons per ton.

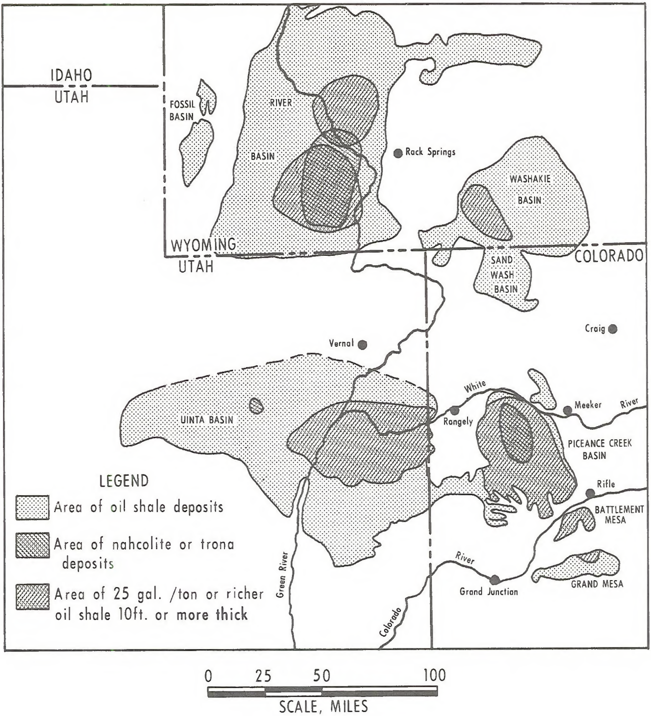

Figure I-3 Oil Shale areas in Colorado, Utah and Wyoming.

energy source adequate to supplement the Nation's oil supply for many decades.

It has long been known that petroleum liquids and gases can be obtained by heating oil shale in a closed vessel called a retort. Commercial production of shale oil abroad actually preceded by several decades the drilling of the first oil well in the United States. Shale oil industries have been established in many foreign countries in the past and exist today in mainland China and the U.S.S.R.

Domestic interest in the commercial development of this extensive potential source of energy has fluctuated widely. Some oil from shale was produced prior to the 1859 discovery of natural petroleum, but serious attention did not focus on oil shale until immediately prior to 1920, when there was some concern that domestic petroleum resources might become inadequate. Interest subsequently declined at that time as ample supplies of liquid petroleum were discovered and developed.

The Department's accumulated knowledge of this resource and its expected potential was summarized in a Department of Interior Study in 1968 (2). Contemporary and future technologies, and the public policy factors that could influence the rate of development of this resource were delineated. Included also were estimates of the resource size and a summary of land ownership status. Efforts since that study's publication have been concentrated on: (1) analysis of the probable environmental impact of oil shale development, (2) formulation of a prototype leasing program within the framework of existing law, and (3) a program to determine ownership of the oil shale where title conflicts exists.

C. Oil Shale Technology

Two major options are being considered for oil shale developments: (1) mining followed by surface processing of the oil shale and shale oil; and (2) in situ (or in place) processing. Of the two options, only the mining-surface processing approach is believed to have been advanced to the point where it may be possible to scale-up to commercial production in this decade. In situ processing is in the experimental phase; commercial application of this technique cannot be expected prior to 1980. The relative state of knowledge of the various operations required in oil shale processing is shown in Figure I-2.[1/] Subsequent sections of this report review these technologies in more detail. It is apparent from Figure I-2, however, that various technical approaches are available for each phase of the operations, and no single system is likely to dominate the initial development of oil shale.

1. Surface Processing

Until recent years, virtually all efforts to develop oil shale technology were directed toward mining, crushing, and above ground retorting. Oil shale processing in this manner would require the

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1/ Most of the refining operations shown in Figure I-2 would be performed outside of the oil shale region, at refinery centers near markets for the products.

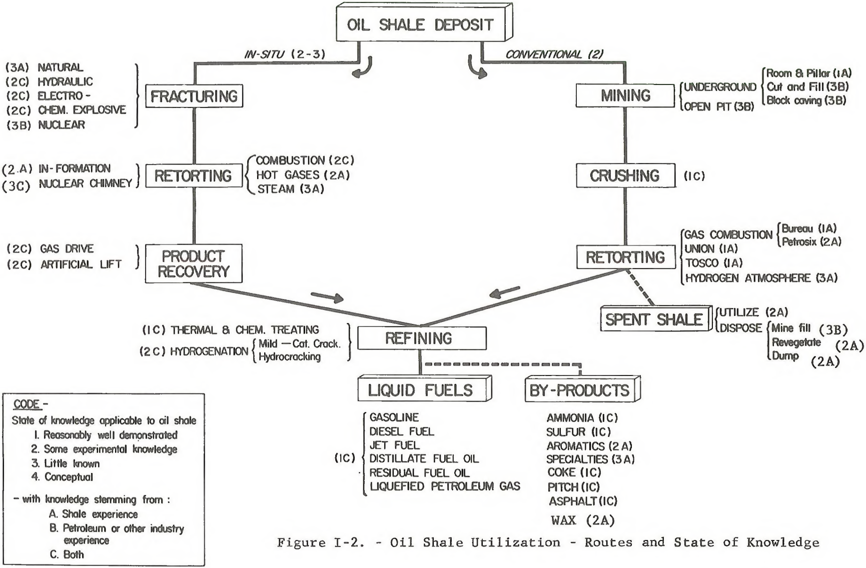


Figure I-2. - Oil Shale Utilization - Routes and State of Knowledge

August 1972

handling of large amounts of materials. Figure I-3 indicates the materials flow through such an operation; beginning with mining and ending with final fuel products and various by-products, in certain locations, the oil shale deposits contain minerals that may be amenable to recovery of additional by-products such as soda ash and alumuna.

a. Mining

Oil-shale may be mined by either surface or under-ground methods. Surface mining, usually termed open-pit or strip mining, requires removal and disposal of whatever overburden is present, followed by mining of the underlying oil shale in a quarry-like operation.

The greatest amount of actual experience in mining oil shale has involved underground mining techniques. Major advances in underground mining of oil shale were achieved by the Bureau of Mines in its oil shale program during 1944-1956. The state of technology as reviewed by the Bureau of Mines in 1970 is described as follows (3):

> "An underground mining method for oil shale was developed and demonstrated by the Bureau of Mines (4) at its oil shale facility near Rifle, Colo., during 1944-56. A "demonstration mine," sometimes referred to as an underground quarry, was opened in a 73-foot minable section of the Mahogany zone to demonstrate the feasibility of room-and-pillar mining methods, to develop and test equipment, and to determine whether low mining costs and high recovery were possible. A two-level operation was adopted: a top heading, 39 feet high; and a bench, 34 feet high.
>
> Room openings and roof-supporting pillars were both 60 feet squire. An extraction ratio of 75 percent. Head and side space thus was sufficient to permit the use of large portable diesel and electrically driven mining equipment, thereby obtaining a high output per man-shift. An average of 150 tons per man-shift was

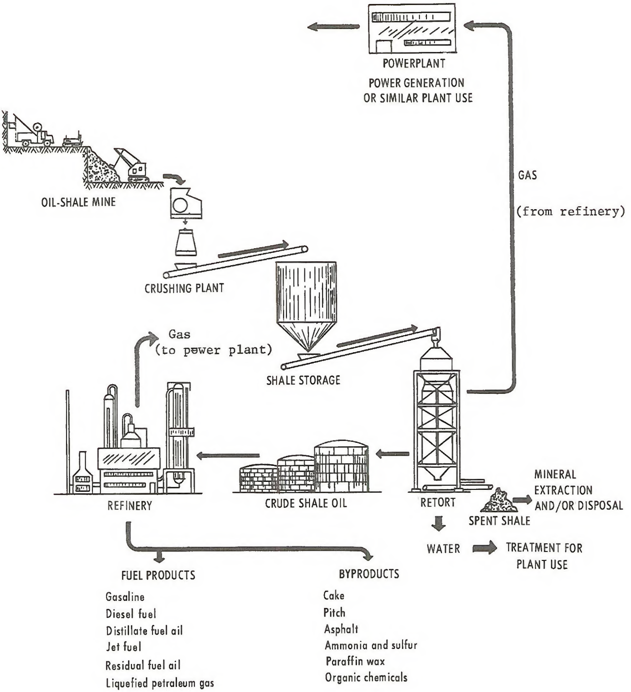
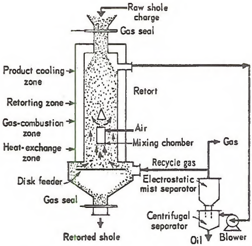
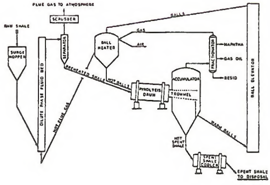


Figure I-3.-Schematic Diagram of Oil Shale Surface Processing



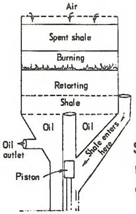
GAS - COMBUSTION RETORT

Recycle gas is mixed with air and burned within the retort. Gases flow upward and shale moves downward.



TOSCO RETORT

Ceramic balls transfer heat to the shale. No combustion takes place in retort.



Shale is introduced near bottom of retort and forced upward. Air enters at the top and flows downward.

UNION OIL RETORT

Figure I-4. - Schematic Representations of Three Oil Shale Retorting Processes achieved for sustained periods during normal operating tests. Special equipment developed for mining the high faces included drilling jumbos, a rotary drill for the benching operations, explosives-loading platforms, scaling rigs, and a mobile compressor and utility station. An electric shovel with a 3-cubic-yard dipper was used to load the broken shale. Diesel-powered dump trucks were used for haulage. Subsequent shale work by industry has followed in general the mining method demonstrated by the Bureau, but has incorporated equipment modernization and improvements in techniques.

If an underground oil shale mining operation were to be undertaken in the near future, it could be expected to incorporate improvements over the Bureau's demonstration mine, such as the following" Changing to rotary drilling in the mine heading as well as in benching; blasting with a more economical explosive, such as an ammonium nitrate-fuel oil mixture; use of modern haulage and loading equipment, and other improvements based on recent advances in quarry and open pit mining engineering. Also, in the interest of safety, a retreat system might be used instead of the advance system that was demonstrated."

Room-and-pillar mining techniques have been improved through subsequent work by: Union Oil Company (1956-58), Colorado School of Mines Research Foundation (1964-67), and Colony Development Operation (1965-present). In considering the future, the Bureau of Mines review (3) stated:

"The room-and-pillar mining system is the only one that has been tested on the oil shales of the Green River Formation. However, open pit mining, highly developed for mining other ores, probably will be practical for oil shale in areas where conditions are favorable. Among the considerations that would be important in selecting a suitable site would be the availability of a satisfactory area for storing the overburden and the ratio of the overburden to the shale to be mined."

b. Crushing and Conveying

Oil shale consists of a solid, largely insoluble organic material intimately associated with a mixture of minerals; a typical composition is shown in Table I-1. Much of oil shale as mined would require crushing and sizing prior to retorting, and the crushing equipment must be designed to overcome a tendency of the oil shale to form slabs.

Table I-1. - Typical Composition of Oil Shale Sections Averaging 25 Gallons of Oil Per Ton in the Mahogany Zone of Colorado and Utah (3)

	Weight-Percent
Organic matter:	
Content of raw shale	13.8
Ultimate composition:	
Carbon	80.5
Hydrogen	10.3
Nitrogen	2.4
Sulfur	1.0
Oxygen	5.8
Total	100.0
Mineral matter:	
Content of raw shale	86.2
Estimated mineral constituents:	
Carbonates; principally dolomite	48
Feldspars	21
Quartz	13
Clays, principally illite	13
Analcite	4
Pyrite	1
Total	100

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The subject of crushing oil shale has also been investigated, as summarized in the same Bureau of Mines review (3), which states:

> "Under its 1944-56 program the Bureau of Mines obtained substantial data on crushing Colorado oil shale using different types of equipment including jaw, gyratory, impact, and roll crushers (5). In addition, data were derived from a number of crushing tests of short duration which were conducted cooperatively between the Bureau and several industrial machinery companies. Industry subsequently has gained experience and additional knowledge in the crushing of oil shale."

Transfer of the shale between different parts of the complex can be achieved by a number of methods, but the most probable means would be truck or belt haulage from the mine, with subsequent transfer by continuously moving belts. Belt conveyors can be equipped with hoods and dust collectors to capture most of the dust that may be generated, and are widely used in many industrial applications as a low cost, efficient means of moving large volumes of materials. Dust control equipment and procedures also can obviate dust release problems in crushing and screening plants with a high degree of efficiency.

c. Retorting

After mining and crushing of the oil shale, it is conveyed to a processing unit called a retort, in which the oil shale is heated to the temperature (about 900°F) at which is a solid organic material in the oil shale (kerogen) is converted to oil. The above review (3) described the state of retorting processes as follows:

"Many retorting processes for oil shale have been patented in the last half century, and new patents continue to be issued. Only a few processes, however, are generally considered to be prime candidates for early commercial use in first-generation retorting plants in Colorado, Utah, and Wyoming. These few processes each have attractive features; they are generally compatible with requisites for successful application to Green River oil shales; and they have been demonstrated in moderate-size to fairly large-size experimental equipment. All retorting processes have one fundamental characteristic in common; namely, heating the shale to at least the pyrolysis temperature, which ranges from 800° to 1,000°F. This is the only practical means known for producing shale oil. Although the major pyrolysis product is oil, both gas and carbonaceous residue also are formed.

Individual retorts having capacities of about 10,000 tons per day generally are visualized as an appropriate size for the first commercial retorting plants. Designs of hypothetical retorts approaching this size have been incorporated in recent cost-evaluation studies. A practical approach to scaling up to such a size in this new field of technology involves working out solutions to engineering problems in a series of progressively larger experimental plants, the largest usually being referred to as a prototype of a commercial unit."

The principle mechanical features of the most advanced retorting processes are shown schematically in Figure I-4.

(1) The Union Oil Retort.- The retort developed by Union Oil Company of California was tested on a demonstration scale of about 1,000 tons/day, from 1956 to 1958. This retort consists of a vertical, refractory-lined vessel. It operates on a downward gas-flow principle, and the shale is moved upward by a unique charging mechanism usually referred to as a "rock pump." Heat is supplied by combustion of the organic matter remaining on the retorted shale and is transferred to

the oil shale by direct gas-to-solids exchange. The oil is condensed on the cool, incoming shale and flows over it to an outlet at the bottom of the retort. This process does not require cooling water. The company announced that operation of the plant had yielded enough information that larger equipment could be designed and constructed whenever energy demand and economic conditions warranted. (6)

(2) The TOSCO II Retort. - Colony Development Operation, now comprised of the Atlantic Richfield Oil Company, the Standard Oil Company of Ohio, the Oil Shale Corporation (TOSCO), and the Cleveland Cliffs Iron Company, have conducted operations beginning in the mid-1960's and into 1972 that included construction of a "semi-works" plant using the TOSCO II retort, and the attendant opening of a mine. The TOSCO II retort is a rotary-type kiln utilizing ceramic pellets heated in external equipment to accomplish retorting. Shale feed of minus 1/2-inch size is preheated and pneumatically conveyed through a vertical pipe by flue gases from the pellet heating furnace. The preheated shale then enters the rotary retorting kiln with the heated pellets where it is brought to a retorting temperature of 900°F. by conductive and radiant heat exchange with the pellets. Passage of the kiln discharge over a trommel screen permits recovery of the pellets from the shale dust for reheating and recycling. The spent shale is routed to disposal by a screw conveyor. Excellent oil recoveries and high shale throughput rates have been reported (7).

(3) The Gas-Combustion Retort.- Of the numerous retorts studied in the Bureau of Mines program, the gas-combustion retort gave the most promising results. This retort is a vertical, refractory-lined vessel through which crushed shale moves downward by gravity. Recycled gases enter the bottom of the retort and are heated by the hot retorted shale as they pass upward through the vessel. Air is injected into the retort at a point approximately one-third of the way up from the bottom, and is mixed with the rising, hot recycle gases. Combustion of the gases and some residual carbon from the spent shale heats the raw shale immediately above the combustion zone to retorting temperature. Oil vapors and gases are cooled by the incoming shale and leave the top of the retort as a mist. The novel manner in which retorting, combustion, heat exchange, and product recovery are carried out gives high-retorting and thermal efficiencies. The process does not require cooling water, an important feature because of the semi-arid regions in which the shale deposits occur. This program was terminated before operability of the largest of three pilot plants had been demonstrated, but the process appears to have promise. (8)

From 1964 to 1968, the Bureau of Mines facilities near Rifle, Colorado were leased by the Colorado School of Mines Research Foundation and were operated under a research contract with six oil companies: Mobil, which acted as project manager, Humble, Phillips, Sinclair, Pan American, and Continental. The first phase of the research, which lasted approximately 2 years, was devoted primarily to studying the gas-combustion retorting process in two small pilot plants (normal capacities of 6 and 24 tons/day) that had been constructed by the Bureau (8). The second phase, started in April 1966, involved both mining and retorting. The retorting included use of the largest gas-combustion process pilot plant (originally rated at a capacity of 150 tons/day) at the facilities. This phase lasted about 18 months. Significant process improvements were achieved, particularly in regard to throughput capacity per unit size of retort. Under the terms of the lease all data obtained in the program became public property after a 3-year confidentiality period. These data have been published by the Bureau of Mines. (9, 10)

(4) Separation Systems.- Beyond having a common heating requirement, retorting processes also require provision for effective recovery and separation of the oil and gas products. Typically, this procedure involves transfer of the mixed product via a piping system to a closed train of commonly available equipment such as impingement-type separators, centrifugal separators, and electrostatic precipitators. Absorbers and similar recovery equipment commonly used in petroleum refineries also may be included. Regardless of the details of the recovery system, which would vary depending upon the retorting process and operating parameters, the principal functions to be served are separation and recovery of oil and gaseous products in relatively clean states. Concurrently, the water inevitably produced in any retorting process and any particulates that may carry over from the retorts are trapped.

(5) Characteristics of Products from Surface Retorts.- Crude shale oils produced from surface retorts may generally be classed as low-gravity, moderate-sulfur, high-nitrogen, oils by petroleum standards. Characteristically, these are more viscous and have a higher pour point (congelaing temperature) than many petroleum crudes. Oils from the different processes also differ somewhat from one another as shown by the selected characterization data of Table I-2. Gas properites and yields also will vary from process to process. Internal-combustion retorts such as the gas-combustion or Union Oil Company types produce gases diluted with the products of combustion and the inert components of the air introduced to support combustion. The gas from an indirectly heated retort such as the TOSCO type is composed only of the undiluted components from the oil shale itself. Gas characterization and yield data generally illustrative of each general type of retort are presented in Table I-3.

The gas produced from internal combustion retorts has a low heating value of the order of 80 to 100 Btu/scf, and cannot be economically transported a substantial distance; however, it is of value in the plant vicinity. Commercial considerations generally envision the productt gas geing used as a fuel for generation of power and process steam. Use of the higher heating value gas from the indirectly heated retort would be less limited; however, this gas probably would be used in the plant as a fuel to heat the ceramic balls which in turn, provide the energy needed to heat the shale to retorting temperature.

Table I-2. Characteristics of Crude Shale Oils

	Retorting Process		
	Gas Combustion	Union 1/	Tosco
Gravity, °API	19.7	20.7	28.0
Sulfur, wt. pct.	0.74	0.77	0.80
Nitrogen, do.,	2.18	2.01	1.70
Pour Point, °F	80	90	75
Viscosity, SUS @100 °F	256	223	120
Reference Source	(10)	(40)	(28)

1/ Typical of product from original Union process.

Table I-3. Characteristics and Yields of Retort Gases

	Type of Retorting Process		
	Internal Combustion		Indirectly Heated
Composition, vol. pct.	2/	2/	
Nitrogen 1/	60.1	62.1	--
Carbon monoxide	4.7	2.3	4.0
Carbon dioxide	29.7	24.5	23.6
Hydrogen Sulfide	0.1	0.1	4.7
Hydrogen	2.2	5.7	24.8
Hydrocarbons	3.2	5.3	42.9
Gross Heating Value, Btu/scf	83	100	775
Molecular Weight	32	30	25
Yield, SCF/bbl. oil 3/	20,560	10,900	923

1/ Includes oxygen of less than 1.0 volume percent.
2/ First analysis reflects relatively high-temperature retorting in comparison with second, promoting higher yield of carbon oxides from shale carbonate and relatively high yield of total gas.
3/ Oil from the retort.

Sources: References (40, 10, 41, 28, and 42, respectively.)

Regardless of the manner in which the various retort gases were burned to utilize their fuel values, sulfur control would be required to meet air quality standards. In this regard, standard industrial treatment could be used to remove sulfur from the retort gases as such, or, optionally, could be applied to the stack gases of the burning equipment. In the particular case of the TOSCO process, the first option almost certainly would be adopted, since the sulfur concentration (as hydrogen sulfide) is high enough to permit recovery of sulfur as a byproduct. Also, in the case of the TOSCO process, control of particulate matter in the fuel gas from the ball heater would be required, involving the use of wet scrubbers or other efficient treatment systems.

d. Waste Disposal:

Water is an inherent byproduct of oil shale retorting. It may be produced at a rate as high as 10 gallons per ton of shale retorted but, more typically, it will range from 2 to 5 gallons per ton. It will contain a variety of organic and inorganic components as shown by the typical analyses of produced waters in Table I-4. These foreign constituents can be effectively removed, as indicated in the last column of Table I-4, through addition of lime, heating, and contacting with activated carbon and ion-exchange resins. Other promising approaches such as electro-oxidation are being tested by the Bureau of Mines. Retort waters, after treatment as necessary to remove odorons, volatile components, would be used to wet the spent shale during disposal operations and therefore be trapped within the shale matrix and/or by chemical reaction at the surface of the shale to provide pile stability (12)

Table I-4. Composition of Raw and Treated Water

Source: Reference (11)

	Raw Water from Internal Combustion Retorts		Treated Water
Component, grams per liter			
Ammonia	2.4	8.9	nil
Organic Carbon 1/	2.5	n.d. 2/	nil
Organic Nitrogen 1/	1.0	n.d. 2/	nil
Sodium	0.5	1.0	0.06
Carbonate	20.8	14.4	0.18
Chloride	1.8	5.4	0.01
Nitrate	Trace	Trace	nil
Sulfate	1.2	1.7	nil

1/ Organics present as complex mixtures of amines, organic acids, organic bases, and neutral compounds.

2/ Not determined

Source: Reference (11)

(2) Spent Shale.- Depending on the grade of shale being processed, the weight of spent shale is about 80 to 85 percent of that of the originally mined oil shale. The remainder of the original shale weight is accounted for by the oil and gas products recovered during retorting. Table I-5 lists the relationship of mined oil shales, shale-oil produced, and spent shale volumes for various rates of shale oil production. The volume of the spent material, even after compacting, is at least 12 percent greater than its in-place volume. This is due to void spaces in the mass of crushed and retorted material which are not present in the shale prior to mining.

Disposal methods for this material will vary and depend on the type of mining system used. As indicated above, not all of the material can be returned to underground workings; consequently, surface disposal would be required to some extent in all cases. Depending on the retorting process, the material may vary in particle size from a fine powder to about 10 inches in diameter and would be discharged from the retort as a dry material. For disposal, larger sized materials would probably require crushing, and water (10 to 20 percent by weight) may be added to reduce dusting and aid consolidation of the disposal piles. Transport to the disposal area may be accomplished by a hooded belt conveyor or by a water slurry system, excess water in the latter option being recovered and recycled.

The mineral content of spent shale generally reflects the mineral composition of the raw shale (Table I-6), although many of the original components are altered under the influence of heat in the retorting

Table I-5. Quantities of In-Place and Spent Shales

Upgraded Shale Oil, barrels per day	Shale Mined, million tons per year	Shale Volumes, billion cu. ft. per year		
		In-Place	Spent (loose)	Spent (compacted)
50,000	26.9 - 29.9	0.40 - 0.45	0.60 - 0.70	0.45 - 0 52
100,000	53.8 - 59.8	0.80 - 0.90	1.20 - 1.40	0.90 - 1.04
250,000	134.5 - 149.5	2.00 - 2.25	3.00 - 3.50	2 25 - 2.60
1,000,000	538.0 - 598.0	8.00 - 9.00	12.00 -14.00	9.00 -10.40

Basis: Oil shale assaying 30 gallons per ton; upgraded oil yield of 86 - 95 vol. pct., based on in-place crude shale-oil potential; loosely dumped spent-shale bulk density of 71 - 75 lbs. per cu. ft.; compacted spent-shale bulk density of 90 - 100 lbs. per cu. ft.

step. For example, some portion of the dolomite (a complex of calcium and magnesium carbonates) will be decomposed to yield calcium and magnesium oxides. A typical analysis of spent shale ash, with components exposed as oxides as is normally done for ash analyses, appears in Table I-6. Some components of the spent shale are significantly water soluble, indicating the need to guard against uncontrolled leaching tests have indicated (12, 13, 31) that water after intimate contact with spent shale will be highly alkaline and contain high concentrations of calcium, sodium, and potassium in the form of sulfates. The other components listed in Table I-6 will contribute very little to the mineral content of leach waters.

Experimental work on a small scale (12) indicates that natural surface-cementation reactions will retard leaching of the soluble components in spent shale. Moistening and compacting spent shale as a part of the disposal procedure can materially expedite the cementation phenomenon, resulting in a nearly impervious condition within a few days.

Table I-6. Mineral Composition of Spent Shale Ash

Component	Composition expressed as oxide wt. pct. of ash
SiO_2	42.3
Fe_2O_3	4.5
Al_2O_3	13.0
CaO	23.1
MgO	9.9
SO_3	1.8
Na_2O	3.1
K_2O	2.3

Source: (ref. 8, Pg 11)

e. Upgrading of Crude Shale Oil

Crude shale oils produced at the retort require partial refining before being transported by pipeline for the production of final products. Specifically, a recent review (3) showed that:

> "Numerous combinations of modern petroleum refining processes can be applied successfully to shale oil. This has been demonstrated experimentally by the Bureau of Mines and industry (14). Hydrogenation is the heart of most refining procedures currently considered suitable for shale oil. Hydrocracking, for example, may be applied to crude shale oil or to the product of a preparatory operation such as coking. The naphtha fraction of the resulting hydrocracked product could be catalytically reformed to produce a satisfactory yield of high quality gasoline.
>
> Use of hydrogen in petroleum refining began on a significant scale in the 1950's and has gained widespread use. Earlier, the cost of hydrogen had been prohibitive. Even though hydrogen is much cheaper today, it still would be a substantial cost item in commercial shale oil refining. Hydrogenation is an effective means of removing sulfur, nitrogen, and oxygen from shale oil and of stabilizing the more reactive unsaturated components, thereby reducing their gum-forming and color-forming tendencies. In combination with cracking conditions, gasoline yields can be greatly increased. Excellent yields of high-quality jet, diesel, and distillate fuels also can be obtained.
>
> It is generally considered that satisfactory commercial shale oil refining facilities could be built, or existing units adapted, without going through an elaborate scaleup program...In 1963, it was reported that some 20,000 barrels of shale oil from the retorting plant of the Union Oil Co. of California had been refined in a small, modern refinery near Grand Junction, Colo., and the products marketed and utilized satisfactorily. More recently, Union was reported to be building a large refinery in the Chicago area that would be capable of processing shale oil and oil from Canadian tar sands."

Properties of an upgraded shale oil appear in Table I-7; for a comparison to raw shale oil see Table I-2. Additionally,

Table I-7. Properties of an Upgraded Shale Oil

Property	Value
Gravity, °API	46.2
Sulfur, wt. pct.	0.005
Nitrogen, do.	0.035
Pour Point, °F below	50
Viscosity, SUS @100 °F	40

Source: Reference (28), page 165.

the upgrading procedure will yield high-quality gas for use within the plant, and ammonia and sulfur byproducts. Depending on the conditions employed, excess gas may be available for generating off-site power for direct use in nearby communities.

Upgraded shale oil could be moved to refining centers via pipelines. Some of this oil may move to the west coast; however, the timing of shale oil production and that of the expected North slope oil[1/] indicates that shale oil will be largely directed toward Chicago and other Midwestern refining centers. The principle existing pipelines are shown in figure I-5. Possible shale oil connecting lines are shown on this figure as crossed lines.

1/ For a complete analysis, see Volume II.

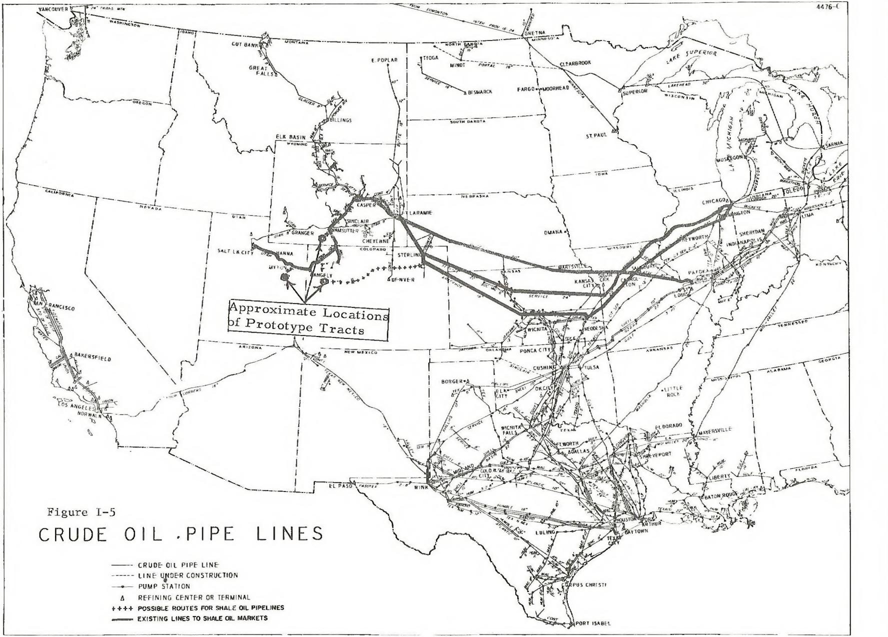


Figure I-5

CRUDE OIL PIPE LINES

- CRUDE OIL PIPE LINE
- LINE UNDER CONSTRUCTION
- PUMP STATION
- Δ REFINING CENTER OR TERMINAL
- ++++ POSSIBLE ROUTES FOR SHALE OIL PIPELINES
- EXISTING LINES TO SHALE OIL MARKETS

f. Minerals Production

Extensive deposits of sodium minerals, one of which contains aluminum, have been discovered in or associated with the deep oil shales of Colorado's Piceance Creek Basin. Dawsonite, the aluminum bearing mineral, was discovered in 1958 but not investigated extensively until the enormous quantities present were revealed in 1966. Preliminary surveys indicate that an estimated 27 billion tons of dawsonite, equivalent to 9.5 billion tons of alumina, are present in a 150,000 acre section of the central Piceance Creek Basin in association with other sodium minerals, the most important of which in nahcolite. The nahcolite is estimated at 30 billion tons (2). The presence and concentrations of these minerals suggested the possibility for efficient and economic extraction of alumina and soda ash values. It was recognized also that the economics of extracting shale oil might be enhanced if such mineral products could be co-produced in significant amounts at an added cost appreciably less than the net market value of the co-products.

A number of private companies and the Federal Government have conducted laboratory and pilot plant research on nahcolite processing and on alumina recovery from dawsonite, and several patents have been issued (15 to 20). No commercial scale applications have been made for recovery of other minerals, but the technology has been reasonably well developed on a small scale. In concept, part of whatever nahcolite is present may be removed in concentrated form as a side stream from the crushing step preparatory to retorting of oil shale. The dawsonite and the rest of the nahcolite (or more properly, derivatives of these minerals) must be recovered from the spent shale after the retorting step. In this regard, the spent shale is roasted to remove whatever carbonaceous residue is present. The nahcolite would have been converted to soda ash, which is readily removable by leaching, and the dawsonite will be in the form of sodium aluminate. The sodium aluminate then may be extracted with dilute soda ash or other alkaline solution, carbonated to yield aluminum hydroxide, precipitated, and finally calcined to yield high-grade alumina for ultimate use in the manufacture of aluminum metal. The spent shale, minus associated minerals, must then be disposed of.

The spent residue would be wet--probably finely divided and in a slurry form--but would not be materially different otherwise from the spent shales that were discussed earlier. The volume, however, may be up to 20% less as a result of saline mineral recovery.

Based on an average dawsonite concentration of 11 weight-percent and nahcolite of 15 weight-percent (2, pg. 71), it was estimated that a single plant that produces 35,000 barrels per day of upgraded shale oil could also yield about 3 percent of the nation's anticipated need for aluminum in 1980. That same plant would also provide about 15 percent of the nation's projected 1980 need for soda ash.

2. In Situ Processing

In situ experimentation has been conducted by various companies and the Bureau of Mines for a period of years. This process involves underground heating by such means as combustion in the formation, introduction of hot natural gas, and introduction of superheated steam. However, the technology is not yet developed to the extent that prediction of either technical or economic success is warranted.

A key problem is the creation of permeability with the shale matrix Two major approaches are in the early stages of investigation. One approach proposes limited fracturing by conventional means, whereas the other proposes massive fracturing by a nuclear explosion.

Sinclair Oil and Gas Company(recently merged into Altantic Richfield Company), experimented with conventional in situ retorting of oil shale in 1953 and 1954 at a site near the southern edge of the Piceance Creek Basin. From these tests it was concluded that communication between wells could be established through induced and natural fracture systems, that wells could be ignited successfully although high pressures were required to maintain injection rates during the heating period, and that combustion could be established and maintained in the shale bed. (21) Over a period of several years in the mid-1960's, Sinclair conducted field research on the in situ process ar a site near the center of the Piceance Creek Basin where the shale is much deeper and thicker than it was at the site of the first experiment. The results of this experiment were not promising; fracturing techniques that were used did not produce sufficient heat transfer surfaces for successful operation. (22, 23)

Also in the 1960's Equity Oil Company conducted field experiments on in situ processing of oil shale in the Piceance Creek Basin. The process employed the injection of hot natural gas to retort the oil shale rather than using underground combustion for this purpose. However, the experiment suffered large gas losses to the formation. (24)

Several less extensive investigations of the in situ technique have been conducted by various oil companies during the last 10 years or so, but very little has been published concerning the results achieved.

The possibility of utilizing a nuclear explosive to fracture oil shale preparatory to in situ retorting has been under consideration since 1958. A feasibility study for a nuclear experiment (25) Project Bronco, was proposed in the Piceance Creek Basin. Later a similar experiment was proposed for the Uinta Basin. (26) Neither of these experiments is being actively considered at the present time. The lack of firm data precludes further analysis of this technique at this time. If such a project is proposed on public lands, it will require a complete environmental analysis, including the preparation of an environmental impact statement specifically addressed to this subject. Those factors that must be considered, such as ground motion and containment of radioactivity released from the explosion, have been discussed in detail in the concept documents referenced above.

A design concept for conventional in situ retorting based upon contemporary petroleum technology is presented in figure I-6. The essential steps include: (1) well drilling, (2) fracturing to

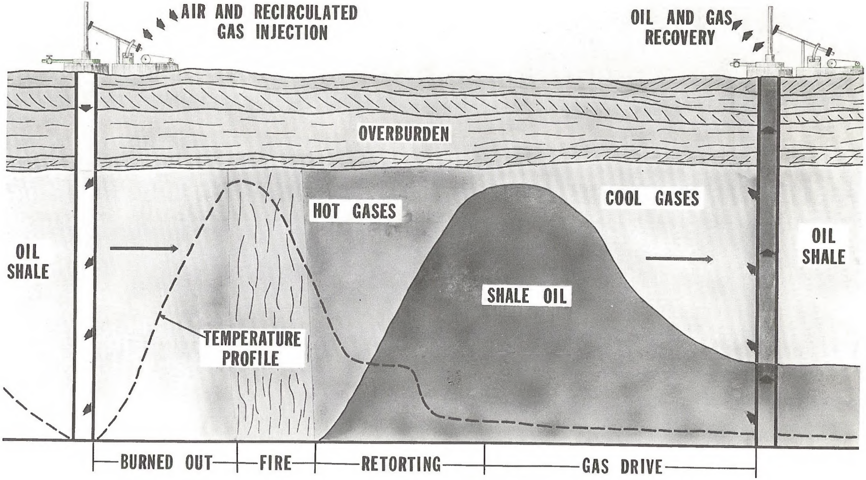


Figure I-6.-Schematic Representation of an In Situ Retorting operation permit heat transfer and movement of liquids and gases, (3) application of heat, and (4) recovery of products.

A commercial in situ processing system has not been demonstrated to date, but a number of field-scale experiments have been conducted by government and industry during the past 20 years, involving wellbores from the surface.

Two major problems encountered from such processing have been

(1) Insufficient naturally occurring permeability, or failure to artificially induce permeability so as to allow passage of gases and liquids; and

(2) Inability to remotely control the process with sufficient accuracy through wellbores from the surface. Besides surface wellbores, other methods proposed for introducing heat underground include mine shafts, tunnels, and fractures created by a variety of techniques.

It is obvious that considerable further improvements in technology are still required before industrial-scale in situ recovery of shale oil could become a reality.

Avaliable information suggests that oils from in situ retorting may be somewhat superior in quality to those produced from surface retorting. Specifically, they appear to have lower pour points, viscosities, and nitrogen contents. This is illustrated by the data in Table I-8 as compared to the data previously presented in Table I-2. In situ oil may be marginally suitable for transporting without upgrasing because of the low pour point; however, no firm conclusions are possible because of insufficient data. Gases produced in the gas/oil separation step shown

Table I-8. Characteristics of Oils From In Situ Retorting

	Bureau of Mines 1/	Sinclair 1/	Equity 2/
Gravity, °API	31.7	30.6	54.2
Sulfur, wt. pct.	0.67	1.28	0.61
Nitrogen, do.	1.35	1.14	0.36
Pour Point, °F	+5	+35	-15
Viscosity, SUS @100 °F	41.0	--	--

1/ Heat supplied by underground combustion.

2/ Heat supplied by introduction of hot natural gas to formation.

Source: Reference (27)

in figure I-6 would have characteristics similar to those shown in table I-9.

D. Environmental Control

The previous sections of this chapter have provided a summary of oil-shale processing techniques as developed through previous small-scale experimental operations. This section examines the environmental impacts that would result from a much larger operation which would involve commercial operations. These impacts include:

(1) Management of solid wastes, (2) Management of wastes within the working areas, (3) Environmental control during in situ processing, and (4) Monitoring. This review of environmental control technologies is made to establish the base against which environmental impacts can be assissed.

1. Management of Solid Wastes

Once the spent shale has been conveyed to a disposal site, provision must be made to create a stable pile and to prevent erosion and/or leaching of sediments and resident minerals.

Stability was studied by the Denver Research Institute (12) which utilized two approaches:

> (1) physical strength studies of shale ash as a function of a number of variables and (2) chemical studies as a function of these variables in order to define the cementing components in the hydration products of shale ash. The variables studied to date include (a) composition of shale ash, (b) burning temperature, (c) burning time, (d) moisture content, (e) degree of compaction, (f) storage time, and (g) storage temperature.

Table I-9. Characteristics of Gases[1/] from In Situ Retorting

Component	Concentration, Vol.%
Nitrogen	73.7
Oxygen	3.4
Propane	0.2
Carbon Dioxide	21.4
Carbon Monoxide	0.1
Hydrogen Sulfide	0.1
Butanes	0.1
Methane	0.5
Ethane	0.5

1/ Heating value approx. 30 Btu/scf
Yield from operation at level of 50,000 B/CD upgraded shale oil approximately 1,485 x 10^6 SCF/CD

Source: Reference (27)

That study showed that the rate of cementation of shale ash is ". . . similar to that in portland cement setting (12, Pg 22 and 92)." Moreover,

> Increased compaction results in greater strengths. Grain size distribution is also important. To secure greatest strength, compaction should be applied soon after mixing with water to eliminate disruption of the initial set. Much compaction can occur under the steady weight of the shale pile before several days have elapsed and setting is too far advanced. Unconfined strengths of 60-70 psi have been obtained under pressures simulating 75 ft. depths with 10% water and preliminary 10% Standard Proctor compaction. For comparison, strengths of 100-200 psi are adequate for some highway base course construction.
>
> Water saturation after initial setup produces no loss of strength with well burned material, indeed some gain was generally observed. Although the present emphasis has been on the study of the cohesive strength of more or less compacted spent shale it should be recognized that sometimes too high a cohesive strength is a detriment if it prevents cracks in the head of a dump pile from self-healing. High cohesive strength, of course, may be of little value if the soil on which a pile is built is weak or may be weakened with moisture.

It is assumed that most spent shale will be initially disposed of in box canyons. Engineering design of this operation must consider the properties of the foundation upon which this material will rest and the angle of repose which will assure frictional stability. In general, it was concluded that (12, Pg 63):

> ". . . a suitably processed spent shale ash will develop sufficient cohesion so that deep, well stabilized dumps with high angles of slope may be constructed. Because of the probable poorer mechanical characteristics of the soil in the bottom of the canyons where the shale ash will

likely be dumped, it is likely that the foundations under the shale ash dumps will limit the allowable safe slope angles and heights which may be built."

At a 45° slope, the tolerable depth may be 100 feet and at 26°, the height may be several hundred feet. The actual slope to be constructed would require many tests to determine the actual characteristics of the surface and subsurface foundation material. A technically feasible scheme that would provide an 18° slope has been proposed (30) to place:

> ". . . processed shale in a series of horizontal layers some one to two feet thick such that the upper surface would always be a temporary surface until the last layer is placed. However, each layer would be started a little further back into the canyon, giving the front surface of the pile, or permanent surface, a 1:3 slope. This slope is well below the angle of repose and insures frictional stability. Overall stability of the embankment is also assured by compaction level, vegetation, and placement of broken rock on the permanent face."

During the buildup of the waste material to its design height, some erosion will occur. The greatest concern is not with the snow and/or rain that occurs throughout the year, but with (12, Pg 62).--

> ". . . occasional flash-floods which may amount to 1.5 to 2.0 inches of rainfall in a few hours. To handle the run-off from the plateau which drains into the canyons it will likely be necessary to either channel the water away from the canyons containing shale ash dumps or to install large conduits in the bottom of the canyons under the shale ash dumps.

Upstream flood control dams and/or conduits can be used to protect the disposal area during buildup. Additionally:

> To handle the run-off from the shale ash dumps from a flash flood, it will likely be necessary to install a small dam or retaining pond immediately downstream of the dump in order to catch the run-off from the dumps . . . ."

This water, including the brines, can then be returned and used in subsequent disposal operations. The concept of collecting surface run-off in ponds downstream of the residue pile has been confirmed by a study conducted by Colorado State University for the Environmental Protection Agency (13, p. 3). That study also detailed the chemical properties of the quality and quantity of run-off from spent oil shale residue due to rainfall. The project consisted of three phases of work (13, Pg 94):

> "(1) Bench scale studies were used to determine (a) permeability, porosity, and particle size distribution, (b) the composition and maximum quantity of dissolved solids leachable by complete slurry treatment; and (c) the composition and quantity of dissolved solids leachable by simple downward percolation through residue columns. (2) Pilot studies were conducted on the TOSCO unweathered spent shale to define (a) the composition and concentration of dissolved solids in runoff from a spent shale pile; and (b) the properties of the residue within the pile before and after rainfall simulation. (3) Data was interpreted using statistical techniques to determine the quantitative relationships between the dependent and independent variables significant to spent oil shale residue leaching."

Specifically, it was shown that:

> "Leaching tests show that there is a definite potential for high concentrations of Na^+, Ca^{++}, Mg^{++} and $SO_4^=$ in the runoff from spent oil shale residues. However, with proper compaction, the piles become essentially impermeable to rainfall."

Rainfall tests were conducted in a large excavation approximately three feet deep, 7 feet wide, and 80 feet long. Water applied over the first experiments totaled 26 inches in 2 days--- nearly two years of normal precipitation for the oil shale areas (31). Other tests were conducted over a period of several months and, ". . . no percolation occurred during the rainfall simulation . . . only minor fluctuations were observed in the moisture content of the shale below the 9 inch depth . . . ." (13 p. 73)

Permeability of the residue to water was also shown to decrease with time, the most likely reason being due to the swelling of shale due to the hydration effects of the sodium ion (13, p.71). In addition,

> "Drying of the shale surface causes movement of water from the interior to the surface by capillary action. On reaching the surface, the water evaporates leaving behind a white deposit that is clearly visible on the black surface. This deposit is dissolved during the rainfall with the result that both concentration and composition of dissolved solids in the runoff water vary with time and depend on the amount of drying prior to the rain. . . . The rate at which the deposit is formed therefore is clearly dependent on the rate at which capillary action can carry the very concentrated solution from the pores within the shale residue to the surface, because the material can be evaporated more rapidly than it can be transported to the surface by capillary action. (13, p. 55)"

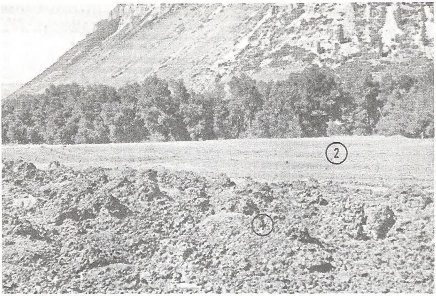
These results indicate that water contamination due to leaching will be negligible. Other studies are currently underway on the effect of snowfall. While as yet incomplete, "...snowfall eliminates the compaction in the top foot or so, and at least 2 feet of the residue becomes permeable to water." (13, p. 91) During the active buildup of a disposal area, snowfall would probably not present any uncontrollable leaching problems since the addition of new material and compaction would be a continuous process. Once the stabilized pile had reached its ultimate height, however, it would probably be necessary to protect the top layer with the addition of native soils prior to revegetation.

Spent shale is a complex waste product whose physical and chemical properties will vary widely. Primary controlling factors are: (1) composition of the oil shale before retorting, (2) preparation of the shale for retorting, (3) type of retorting process used, and (4) the conditions encountered after retorting. Little systematic investigation of revegetation requirements was undertaken through the 1950's, but increasing attention has been given to this aspect of solid waste management in recent years.

Natural revegetation does take place with time as shown by observation of the spent oil shale area left by the Bureau of Mines at its Rulison, Colorado operation in the 1920's and the Union Oil Company site which was abandoned in the 1950's. The first large scale test of revegetation, was undertaken by the Union Oil Company in 1967 when they trucked to a disposal site about 100,000 tons of material of the type produced from their retorting process (figure I-7a). After leveling and compacting, the area was seeded with grasses. By irrigating and applying a fertilizer, a grass cover was developed. The plants have reseeded themselves in subsequent years without further maintenance to produce, by 1970, the vegetation growth shown in figure I-7b.

A systematic investigation of research was initiated by the Colony Development Operation, beginning in 1967. This work, which is still in progress, has produced an increasing body of knowledge on practical methods

Figure I-7A - Union Oil Company Spent Shale Revegetation Experiment, 1967



LEGEND:

(1) Newly dumped spent shale

(2) Dumped area prepared for seeding

Figure I-7B - Union Oil Company Spent Shale Revegetation Experiment, 1970

for accelerating the vegetation process. Under a grant by the Colony group, researchers at the Colorado Agricultural Experiment Station investigated the chemical and physical properties which affect plant growth. The results of fertility and salinity analyses from both TOSCO and Gas Combustion spent shale samples were reported as shown in table I-10. (32)

The conductivity determinations show that all of these untreated materials are too high in soluble salts for normal plant growth. In addition, the pH needs to be lowered. Soluble Na is the principal cation present in the samples (except F), ranging from 24 percent to 74 percent of the total. Normally, plants will not grow satisfactorily where Na constitutes more than about 50 percent of the water soluble cations in the saturation extract.

A major conclusion of the study is that reclamation treatments are required to remove excess salinity and the Na ion before normal plant growth can be expected on spent shale.

The greenhouse work has continued to determine the effect of initial soil treatment on grass germination and growth. In a recent review (30) it was reported that:

> "No initial treatment is necessary to satisfactorily germinate and grow the six types of grasses tested: Western Wheat, Tall Wheat, Crested Wheat, Perenial Rye, Brome and Kentucky Blue Grass. The addition of sawdust or other organic material to the processed shale leads to total germination and initial growth. Long-term greenhouse growth is dependent only on fertilization rate."

Table I-10.- Fertility and Salinity Analysis of Six Spent Shale Samples

Spent Shale Designation	Lab. No.	Retort Process	Conductivity mmhos/cm $25^{\circ}C$	pH Saturation Paste	pH 1:5 Shale:Water	$CaCO_3$ Equiv. %	Available Nutrients P ppm	K ppm	Zn ppm	Fe ppm
A	3766	TOSCO II	16.0	9.7	9.9	40.0	8.5	27	-	-
B	7972	TOSCO II	11.3	9.1	9.4	11.0	3.7	40	10.0	40
C	4216	TOSCO II	26.0	8.9	9.3	31.2	6.7	135	8.4	40
D	240	Gas Combustion	9.0	8.6	9.2	31.4	5.6	360	4.7	40
E	241	Gas Combustion	22.0	8.7	9.0	31.2	3.6	400	5.8	40
F	243	Gas Combustion	12.0	8.7	9.0	30.8	3.6	400	2.9	40

Source: Reference (32)

Beginning in 1967, a series of outside test plots were planted at the Colony Development Operations semi-works plant near Grand Valley, Colorado. The objectives of the program (33, p. 113) were to:

> ". . . reduce the alkalinity, increase the nutrient level, and reduce the surface temperature, which tends to be high because of the dark color of the material. The plots were in four basic units for study of the effects of water rate, depth of planting, artificial seed bed cover, and soil treatments. It was found that by planting seeds 1/4-inch deep in leached soil, fertilizing, and covering with a commercial seed bed cover, a viable ground cover of native grasses was obtained.
>
> Using the success of the 1967 tests as a guide, a demonstration plot was constructed on the processed shale site at the Colony semi-works plant in 1968. Working with the State Forest Service, deciduous and conifer trees were planted along the boundaries of the plot. Local shrubs and plants were also transplanted in the area in addition to native grasses. The results were good, although deciduous trees suffered badly from heavy snows, rolling rocks, and deer. The other plants were found to be hardy. The demonstration plot has now completed its third growing season with continued excellent results."

Further details of this work was given in a recent review (30) which stated:

> " . . . we applied a custom commercial fertilizer at the rate of 150 pounds per acre twice per year and applied water by sprinklers at 1 inch per week during the summer season (approximately 10 weeks). Healthy stands of Western Wheat and Crested Wheat now exist in the thick cover of Kentucky Blue Grass. The root zone of the Kentucky Blue Grass penetrates over 11 inches into the processed shale. We expect that the Wheat grasses, and particularly the Western Wheat, will begin to stool and spread beginning this next growing season. The native Sage shows good health and growth. Like the grasses, we expect pronounced growth from the evergreens beginning this next growing season."

A recent picture (34) of the test plot is given in figure I-8.

Figure I-8. Colony Development Operation Spent Shale Revegetation Experiment, 1970

This accuumulated body of knowledge has led to the following concepts (30) for revegetation during commercial operations:

> ". . . we anticipate that in any commercial operation the permanent processed shale surface will be planted in grass as a temporary cover to control erosion. Such cover grasses can be established twice per year, spring and fall, so that only a small section of the permanent surface needs to be transitional. Later, cover of the permanent surface with strategically placed rocks and boulders from the surrounding cliffs, along with the native grasses and shrubs, would provide permanent cover and conform the shale pile to blend to the natural surroundings. We expect that such vegetation would require fertilizing and watering for a few seasons but ultimately would become self-sustaining. Additional research is being done to determine fully these requirements. Some grasses on an experimental processed shale plot have survived one season without care after two seasons of fertilizing and watering. This isn't too surprising because processed shale is quite similar to natural soils in the area with exception of a carbon residue and somewhat higher concentration of salts.
>
> Research in the vegetation area will continue, but from past results coupled with the similarity between processed shale and natural soil, we see no problem in establishing native vegetation on the permanent surfaces of the processed shale embankment. Moreover, the ultimate surfaces will support greater vegetation and from this standpoint represent an improvement for the general area."

A test embankment is scaled to represent about an 18° slope and revegetated with a wide variety of grasses is shown in figure I-9 (35). Additional research is required to attain longer range revegetation goals to re-establish the natural plant community, or suitable replacement, to serve as wildlife food and cover. Native sage, Englemann Spruce and juniper have been successfully transplanted to oil shale areas. However, a significant body of

Figure I-9. Colony Development Operation Test Disposal Development research experience indicates that re-establishment of the fuller range of native browse and cover species, such as mountain mahogany, shadbush and bitterbrush, may be difficult and time-consuming.

Particular emphasis is needed on developing additional techniques to create nutrient and top soil structure suitable for re-establishment of permanent vegetations. Important variables requiring study include particle size of spent shale, degree of fertilization, addition of top soil or overburden, and extent of moisture control through mulching or irrigation. As large scale operations evolve and as retorting and waste production become better defined, cooperative industry-government efforts are desirable to relate and adapt the information to existing or potential oil shale operations.

2. Management of Wastes Within the Working Areas

The complete flow of materials through an oil shale processing complex is outlined in figure I-10.[1/] This section describes the control measures that would be incorporated into a plant designed to minimize impact on the environment.

a. Mining

Plans for development would have to be approved for any new mine on public or private lands as required by applicable Federal and State laws, and the mine would be inspected to insure compliance with the approved plan and with all mine health and safety regulations.

An estimated 1.6 million tons of oil shale have been mined from experimental operations by the Bureau of Mines and by industry. No fatalities are known to have occurred from any of these operations.

Water has not been a problem in the few oil shale mines opened to date as these have been naturally well drained and the oil shale is dry. However, the volume and quality of water that may be encountered would vary throughout the three-State region as described in subsequent chapters of this regional review.

Water may be encountered in sinking deep shafts, but these shafts can be grouted or cased to stop water encroachment. Drain water into the mines would be collected and pumped to the surface for on site use, or can be controlled by pumping dewatering wells in the vicinity of the shaft. Water from surface mines can be controlled through wells

1/ For the quantities of material that would be expected, see Tract Document, Chapter .

drilled around the mine perimeter. Withdrawal from these wells would be at a rate sufficient to maintain the water table below the working floor of the mine. Saline water encountered in mining may be used in the disposal of processed shale, except possibly in laying the uppormost, permanent layer, thereby minimizing or even eliminating any water disposal problems.

Estimates vary as to the amount and quality of the ground water that may be encountered from an underground or surface mine, potable water would be segregated from saline water for subsequent use in other processing steps. Excess saline water above plant requirements would not be discharged into surface waters. A possible disposal méthod is to pump the water into similar underground aquifers. Each productive oil-shale site will have its own characteristics which will dictate the appropriate water disposal technique.

Dust measurements made during actual operations have shown that oil shale dust due to blasting can be readily controlled in large, well ventilated mines. Mine dust particles less than 10 microns have been reported (30)which indicate an average count better than applicable health standards.

The amount of shale which can be removed without significant subsidence of the land surface depends upon the size and spacing of the rooms and pillars, physical properties of the formation, and depth

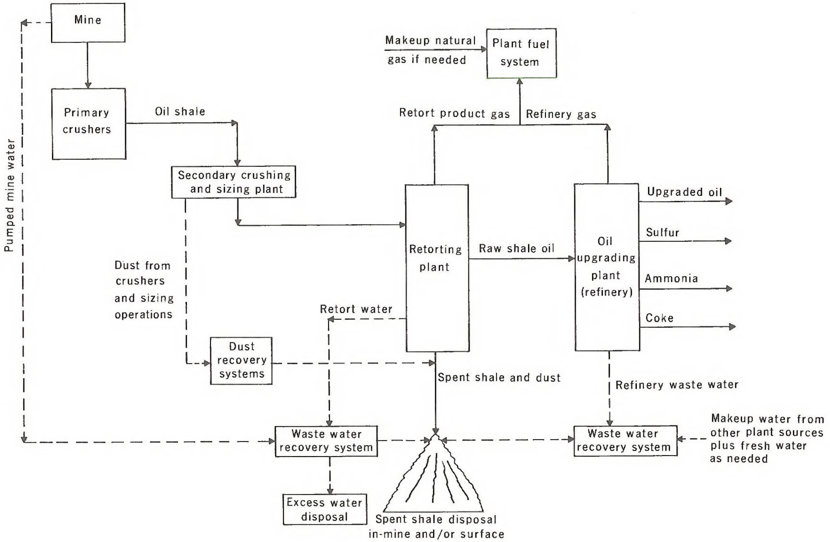


Figure I-10. - Flow Diagram
Underground Oil Shale Mine anu Processing Unit

of overburden. Assuming an average overburden of 1,000 feet, between 50 and 60 percent of the shale could be removed without significant surface effect. Percentage of extraction usually decreases as depth increases, but back filling with retort residue would possibly permit increased extraction of the shale with little additional adverse subsidence effects. These effects can be calculated once the physical properties of the shales at particular sites are determined.

If the material is to be returned to a worked out area of the mine, a slurry system would probably be used. Although this has not been attempted for spent shale, experience with other materials and limited tests with shale indicate the slurry could contain 50 percent solids. After a reasonable time, the impacted material would dewater to 70 to 80 percent solids and be relatively stable. Draining water would be collected and recycled into the slurry disposal system.

b. Crushing and Conveying

A typical system for sizing and conveying mined oil shale is shown in figure 1-11.

The only significant environmental factor in crushing oil shale, as in most crushing operations, is particulate emissions. There are no liquid or gaseous effluents generated in the crushing.

Particulate emissions in crushing plants are conventionally controlled by water sprays, dust collection, enclosing the plant, filtering and scrubbing the air flow out of the enclosure, or, more likely, a

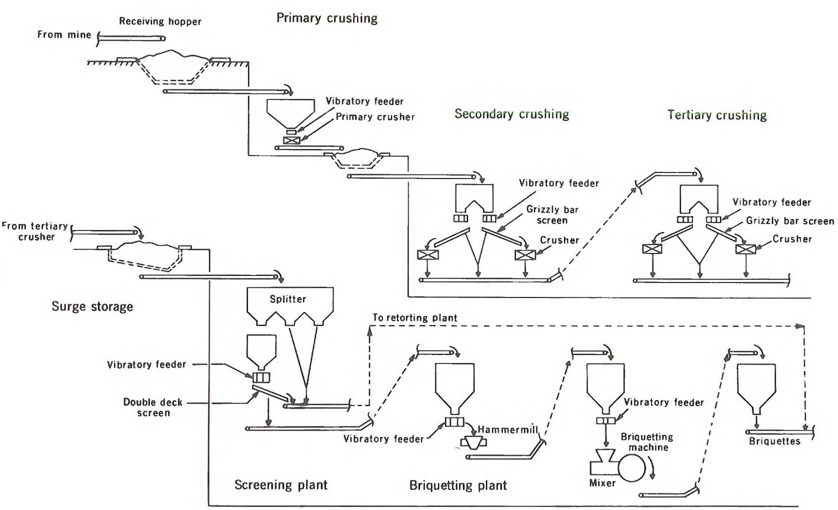


Figure I-11. Crushing, Screening, and Briquetting Plants, Schematic Flow Diagram combination of these. The enclosure and attendant air cleaning system should be adequately designed to protect the ambient air. Dust suppression and collection are used to provide good working conditions within the enclosure. Fines collected may be briquetted for subsequent retorting as shown in figure I-11 or may be used directly in the TOSCO process. Dust trapped by water would be disposed of in spent shale disposal.

c. Retorting

A schematic flow diagram of a gas combustion retort is shown in figure I-12. Regardless of the retorting process, gases would be coproduced with the oil product. The mixture of oil and gas products would be conducted via closed system from the pyrolysis section of the process operation to a separation and recovery section, in a state varying from true vapor to mist to liquid, depending upon the particular process and its operating conditions. Treatment to recover the maximum amount of oil also would remove water and particulate matter. The remaining product gases contain small concentrations of sulfur, which may or may not be economically recoverable.

In the case of the TOSCO process, the ball heater (see figure I-4) represents a potential source of particulate emissions not encountered with the other advanced retorting processes. In this unique situation, wet scrubbers have been shown to be effective for control of particulates. The wet material and any excess water would be added to the spent shale system.

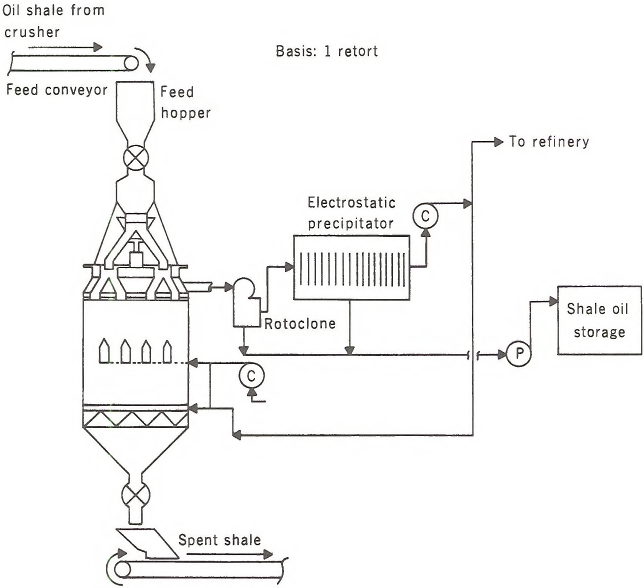


Figure I-12 Schematic Flow Diagram of Retorting System

Water produced in retorting also would be used to wet the spent shale, along with the relatively small amounts produced as blowdown from boilers, discarded from cooling water systems, and collected from similar plant sources. Before such use of retort waters, stream stripping would be required to remove volatile organic matter, such as phenols, and any sulfide. These latter materials would be recovered in the ammonia and sulfur byproducts plants. Other organics stripped off would be efficiently incinerated. Any "sour" water from the refining plants also would be handled similarly prior to use in the spent shale disposal procedures. Thus, no release of process waters to surface or general waters in the area would be expected.

d. Upgrading

All of the process shown in figure I-13 for a typical plant to upgrade crude shale oil are being used successfully in metropolitan areas of California under the regulations of the appropriate Los Angeles and San Francisco Bay air and water pollution control authorities (33 Pg 127). During shale-oil upgrading, large quantities of fuel may be burned to supply heat for processes such as distillation, delayed coking, catalytic hydrogenation, and hydrogen production. The products of combustion would contain some oxides of sulfur and nitrogen. The sulfur oxides could be controlled within acceptable limits by the appropriate selection of low sulfur fuel, or by a sulfur-removal stack gas system. Nitrogen oxides could be minimized by design of the combustion unit to avoid the excessive temperatures which lead to the formation of this pollutant.

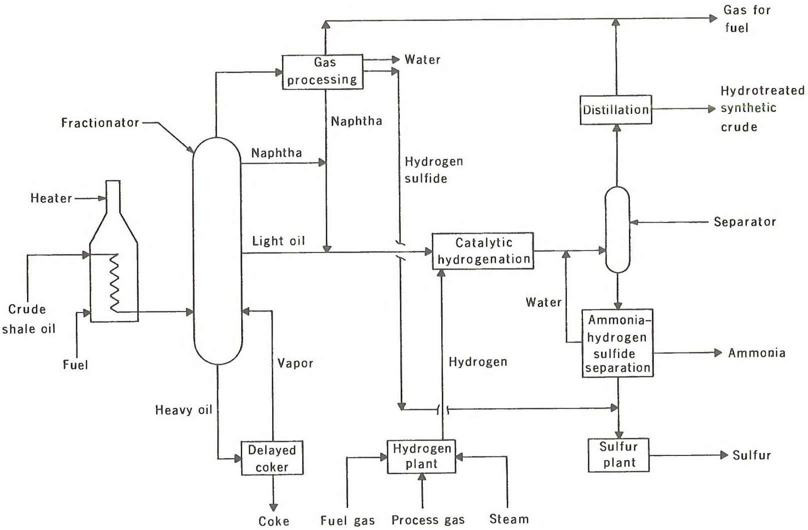


Figure 1-13 Shale Oil Upgrading Facilities

The principal source of contaminated water would be from steam condensed in the gas-processing facilities, which would contain dissolved organic compounds. This water would be purified by conventional refinery treatment techniques and used in processed shale disposal. The water used in the refining cooling towers also would be used in shale waste disposal as mentioned previously in the discussion of retorting.

Small plants may be required to generate electricity for oil shale processing. Cooling water would be provided from recirculating, closed systems and would not be released from the plant confines. Such amounts that were necessary to discard for control of dissolved solids content would be utilized in the processed shale disposal operations.

These power plants would also produce stack gases which could be sources of air pollution. Such contamination would be rigorously controlled to low limits by applying conventional modern utility techniques for removal of particulate matter, and by the control of sulfur and nitrogen oxides emmissions through the use of low sulfur fuels, combustion temperature control, and scrubbing.

The amount of oil in storage will vary depending upon pipelining schedules and operational schedules within the plant. As a reasonable estimate, tankage would be required to accomodate on the order of 7 to 10 days output of upgraded oil product preparatory to pipelining; tankage to the extent of several times this capacity would be provided to serve intermediate storage and unit charging needs within the plant, for example, between the retorting and refining sections. Many standard varieties of tanks are available and suitable for shale oil operations. In general, vapor control types would be used for storage of all volatile oils. Regardless of type, tanks would be diked in accordance with accepted practice, the diked areas being designed to hold about one and one-half times the capacity of the tank, or tanks, within each dike. Thus, even in the extreme case of rupture, oil released will be safely retained in the confined space encompassed by the dike. Specific cleanup procedure in the case of spills will depend upon the particular curcumstance, but any amount of oil sufficient to create a pool in the diked area would be recovered by the use of pumps and returned to suitable storage tanks.

Small amounts of chemicals would be used in the upgrading operations, for chemical conversion and purification. A typical distribution is shown below:

Chemicals Required,
50,000 barrels/day operation

Type	Tons/year
Nickel and cobalt-molybdate Catalysts	1,420
Iron Catalyst	158
Monoethanolamine (MEA)	50
Iron Oxide	30
Char	10

The iron catalyst and oxide, and the char are solids while the MEA is a solid-liquid mixture that is not water soluble. The nickel and cobalt molybdate catalysts would be returned to a plant to be reclaimed, and the other chemicals would be discarded by burial within the spent shale pile. The annual tonnage to be discarded is extremely small in relation to the tonnage of spent shale from a 50,000 bbl/day plant (248 tons as compared to 27 to 30 million tons (Table I-5). This relationship and the impermeable nature of the spent shale preclude any significant environmental problems associated with disposal of chemical wastes.

e. <u>Offsite Requirements</u>

All roadways leading to and servicing a commercial operation would require paving to prevent erosion. If sidehill areas are disturbed by construction activities, erosion controls would include revegetation or broken rock covering. Plant area fencing and selected road fencing may be required to control animal movements.

The average water required for a 50,000 bbl/day processing complex is estimated to be 8.5 cubic feet per second. If this were all imported via pipeline, it would require a 16 inch diameter line. Assuming a ditch double the size of the pipeline and burial below the frost line, a trench approximately 3 feet wide and 6 to 7 feet deep would need to be constructed. Following burial, the surface area would be restored.

Pipelines to handle the oil produced would be installed in the same manner. A 12 inch diameter line would be required for a 50,000 bbl/day plant. A 100,000 bbl/day plant would require a line 18 inches in diameter. The liklihood of a major spill or rupture is remote. Based on pipeline statistics for failure[1/] and a total out put for the prototype leases of 250,000 bbl/day (1), it is estimated

1/ For 1968, 210,000 miles of petroleum pipeline in the U.S. transported 6.5 billion barrels of liquid petroleum commodities. Only six thousandth of one percent of this was spilled due to pipeline failure and much of this was recovered (37).

that the accidental discharge from a total of 150 miles of required pipeline would average about 1 barrel per year. Accidental rupture due to plows, etc. would be largely prevented by the depth of burial and the oil shale area is not an active seismic province. Although remote, ruptures may occur; the amount of oil that may be released would vary considerably and depend on actual conditions. Each linear mile of a 12 inch pipeline will contain about 700 barrels of oil; the 18 inch line will contain about 1,400 barrels. In the event of a rupture, only the oil contained above the point of break may leak out (assuming the pumping equipment has been shut down). Since the terrain over which this pipeline may pass is generally rolling, the oil contained in some 5 to 10 miles of pipe may be released; a maximum of between 3,500 to 14,000 barrels of shale oil. However, the probability of rupture is small (37) and the earth surrounding the pipeline will often provide a high resistance to flow. Such a rupture can be fixed without draining the entire line; broken sections for a major line break are normally replaced or repaired within 12 to 24 hours.

Some natural gas may be needed, but for use within the plant the amount would be small. Depending on the process, there may be a small amount of excess gas for use in nearby communities. Most of the commercial process envision that gas requirements would be balanced with the gas available from various process streams. If required, natural gas pipelines would be constructed similar to those for water and oil.

Power may be produced on site or transmitted to the site from nearby high-voltage lines. The requirements are relatively small (about 100,000 kw hr/hr for a 50,000 bbl/day plant) and may be transmitted either overhead or by underground power lines. Guidelines for such lines on public lands have been published (38).

3. In Situ Processing; Environmental Controls

In situ processing, if it can be developed, would be a dynamic process that continues to move across the surface of the area being developed. To illustrate this process, consider the concept depicted in Figure I-14 for a 90-100 ft. thick strata of Washakie Basin oil shale. Five rows of wells would comprise various operational modes; the first row of wells would be in drilling and preparation stage and the second row would be producing liquid and gaseous products driven by the injection of air of some other oxygen containing gases into the third row. Behind this area, plugging and restoration would be taking place.

In this concept up to 100 wells may need to be drilled each month while the same number would need to be plugged as the combustion zone advanced through the producing zone. The active area encompassed by the five well patterns would total about 115 acres if 100 foot spacing were used between wells. If greater spacing between wells can be used to effectively retort the area, then fewer wells would need to be drilled. While it is hypothesized that a 50,bbl/day shale oil project can be achieved, available technology is very limited to support this conclusion. If it is assumed that such an operation is conceivable, then careful preplanning would be required to reduce the

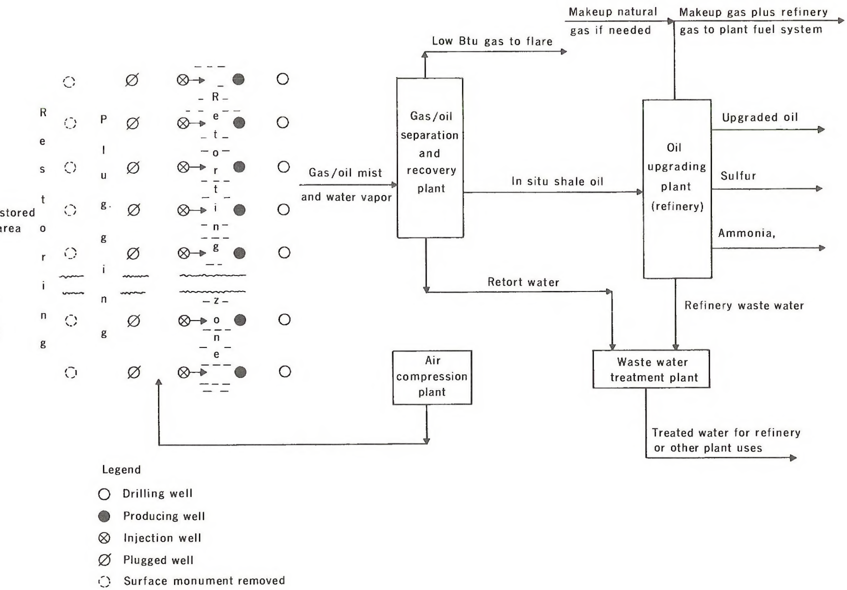


Figure I-14. - Flow Diagram of 50,000 Barrel Per Calendar Day In Situ Recovery System environmental impact caused by a number of truck-mounted drilling rigs and other heavy equipment. Since about 4 wells would be required for each acre, a large portion of each tract would be contacted by such equipment.

Wells would also be required to monitor the movement of subsurface liquids. Due to the lack of in situ technology, only limited operations would be permitted initially under the proposed ptototype program. These would be closely monitored to prevent environmental degradation. Before a commercial in situ operation is permitted on public lands, adequate control methods would need to be demonstrated.

A non-nuclear alternative to the in situ processing method previously described, is to use a combination of underground mining and in situ retorting. This concept visualizes development of a strata of shale with suitable thickness of both in-place shale and overburden. Approximately 25% of the in-place shale would be mined by the room-and-pillar method, and transported above-ground for conventional surface retorting. The remainder would be fragmented, possibly by inducing falls using conventional explosives, to fill the mined-out voids and thus prepare a bed amenable to subsequent in situ retorting by the usual fire-flooding techniques. This concept is yet to be tested and is not, therefore, considered a viable alternative technology.

4. Environmental Quality Monitoring

Monitoring of the air and water quality and of the existing wildlife are needed to establish the base against which changes can be measured. This section considers some of the important parameters that would be considered in designing such monitoring systems.

For air, the area limits and the meteorological factors must be established, e.g. seasonal influences and degree of variability. Topographic influences on air flow and the relation of land elevation to atmosphere stability is particularly important to an evaluation of a specific site. Sampling grids must then be calculated and suitable equipment obtained. A wide variety of equipment is available, based on various principles of monitoring (Table I-11). Once sufficient background data is obtained, it is then possible to assess the actual impact of those air contaminants expected from oil shale operations; particulates, oxides of nitrogen, and sulfur oxides. For a complete review of air quality monitoring, see reference (39).

Water quality of the Upper Colorado River Basin is monitored at stations on the larger tributaries and the main stem of the Colorado River by the U.S. Geological Survey (Figure I-15, and Table I-12). The existing monitoring stations are useful in determining the contribution of dissolved solids from comparatively large areas of the basin. However, the existing network is not designed to identify and assess the effects of specific oil shale developments; additional stations will be required in and near the tracts to separate possible impacts of the oil shale industry from other impacts, such as those due to

Table I-11 . Measurement Principles in Air Quality Monitoring

Classification	Application	Measurement Principle	Energy transducer
Infrared absorption	Gases-CO, hydrocarbons	Absorption of IR energy	Thermistors, thermopiles, capacitor microphones
Ultraviolet absorption	Gases-O_3, NO_2	Absorption of UV energy	Phototubes
Light scattering	Aerosols	Scattering of visible light	Phototubes
Reflectance	Filtered particulates	Visible light reflectance	Phototubes
Ionization	Hydrocarbons	Ionization current measurement	Ionization chamber
Colorimetry	Reactive Gases- O_3, NO_2, SO_2, HF	Absorption of visible or near UV energy by colored compound	Barrier layer cells, phototubes
Conductometry	Acid gases-SO_2	Electrical conductivity	Conductivity cell
Coulometry	Electroreducible and oxidizable gases- O_3, SO_2	Electrical current measurement	Coulometric or galvanic cell
Fluorescence	Fluorescible materials- fluorides	Emission of UV or near UV energy	Phototubes

Source: Reference (39).

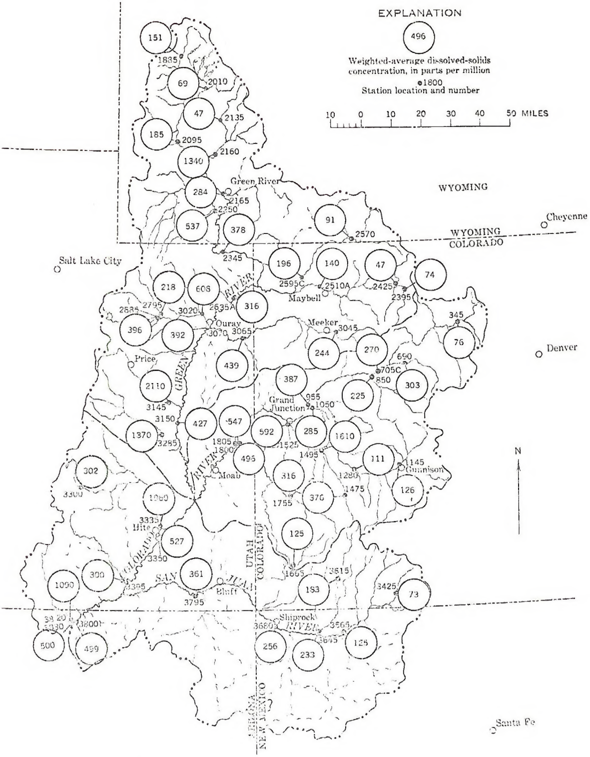


Figure I-15 Weighted-average concentration of dissolved soilds at selected sites in the Upper Colorado River Basin, Water years 1914-57 adjusted to 1957 conditions.

Source: Reference (43).

Table I-12. *—Water and dissolved-solids discharge at selected stations in the Upper Colorado River Basin*

[Water and dissolved-solids discharge for the water years 1914-57 adjusted to 1957 conditions except as indicated]

Station No.	Chemical-quality station	Drainage area (sq mi)	Water discharge: Average (cfs)	Water discharge: Average annual (acre-ft)	Dissolved solids: Weighted-average concentration (ppm)	Dissolved solids: Average discharge (tons per day)	Dissolved solids: Average annual yield per square mile (tons)	Dissolved solids: Average annual discharge (tons)
345	Colorado River at Hot Sulphur Springs, Colo	782	244	176,800	76	50	23	18,260
700	Eagle River at Gypsum, Colo	844	602	436,100	303	492	213	179,700
705C	Colorado River near Glenwood Springs, Colo	4,486	2,399	1,738,000	270	1,750	142	639,200
850	Roaring Fork at Glenwood Springs, Colo	1,460	1,353	980,200	225	821	205	299,900
955	Colorado River near Cameo, Colo	8,050	4,138	2,998,000	387	4,320	196	1,578,000
1050	Plateau Creek near Cameo, Colo	604	235	170,200	285	181	109	66,110
1145	Gunnison River near Gunnison, Colo	1,010	753	545,500	126	256	93	93,500
1280	Gunnison River below Gunnison Tunnel, Colo	3,980	1,303	944,600	111	391	36	142,800
1475	Uncompahgre River at Colona, Colo	437	278	201,400	376	282	236	103,000
1495	Uncompahgre River at Delta, Colo [1]	1,110	286	207,200	1,610	1,240	408	452,910
1525	Gunnison River near Grand Junction, Colo	8,020	2,601	1,884,000	592	4,160	189	1,519,000
1665	Dolores River at Dolores, Colo	556	492	356,400	125	166	109	60,630
1755	San Miguel River at Naturita, Colo	1,080	351	254,300	316	299	101	109,200
1800	Dolores River near Cisco, Utah	4,630	940	681,000	496	1,260	99	460,200
1805	Colorado River near Cisco, Utah	24,100	7,639	5,534,000	547	11,280	171	4,120,000
1885	Green River at Warren Bridge, near Daniel, Wyo	468	540	391,200	151	220	172	80,300
2050	New Fork River near Boulder, Wyo	552	401	290,500	69	75	50	27,390
2095	Green River near Fontenelle, Wyo	3,970	1,609	1,165,000	185	805	74	294,000
2135	Big Sandy Creek near Farson, Wyo	320	86.6	62,740	47	11	13	4,020
2160	Big Sandy Creek below Eden, Wyo	1,610	48.8	35,350	1,340	176	40	64,280
2165	Green River at Green River, Wyo	7,670	1,802	1,305,600	284	1,380	66	504,000
2250	Blacks Fork near Green River, Wyo [2]	3,670	345	249,900	537	500	50	182,600
2345	Green River near Greendale, Utah	15,100	2,271	1,645,000	378	2,320	56	847,400
2395	Yampa River at Steamboat Springs, Colo	604	472	341,900	74	94	57	34,330
2425	Elk River near Trull, Colo	415	544	394,100	47	69	61	25,200
2510A	Yampa River at bridge on county road, near Maybell, Colo	3,590	1,590	1,152,000	140	599	61	218,800
2570	Little Snake River near Dixon, Wyo	988	547	396,300	91	135	50	49,310
2595C	Little Snake River at bridge on State Highway 318, near Lily, Colo	3,355	622	450,600	196	330	36	120,500
2610A	Green River at Jensen, Utah	26,100	4,607	3,338,000	316	3,950	55	1,435,000
2775	Duchesne River at Duchesne, Utah	660	323	234,000	218	190	105	69,400
2885	Strawberry River at Duchesne, Utah	1,040	157	113,700	396	168	59	61,360
3020	Duchesne River near Randlett, Utah	3,920	767	555,700	608	1,260	117	460,200
3045	White River near Meeker, Colo	762	638	462,200	244	420	201	153,400
3065	White River near Watson, Utah	4,020	764	553,300	439	905	82	330,600
3070	Green River near Ouray, Utah	35,500	6,223	4,508,000	392	6,590	68	2,407,000
3145	Price River at Woodside, Utah	1,500	116	84,040	2,110	662	161	241,800
3150	Green River at Green River, Utah	40,600	6,292	4,558,000	427	7,260	65	2,652,000
3285	San Rafael River near Green River, Utah	1,690	141	102,100	1,370	521	113	190,300
3300	Fremont River near Bicknell, Utah [4]	776	85.8	62,160	362	70	33	25,570
3335	Dirty Devil River near Hite, Utah [4]	4,360	102	73,890	1,960	541	45	197,600
3350	Colorado River at Hite, Utah	76,600	14,167	10,260,000	527	20,170	96	7,367,000
3375	Escalante River at mouth, near Escalante, Utah [5]	2,010	85.2	61,720	300	69	13	25,200
3425	San Juan River at Pagosa Springs, Colo	298	403	292,000	73	79	97	28,850
3555	San Juan River near Blanco, N. Mex	3,520	1,519	1,100,000	125	512	53	187,000
3615	Animas River at Durango, Colo	692	859	622,300	183	425	224	155,200
3645	Animas River at Farmington, N. Mex	1,360	971	703,500	233	611	164	223,200
3680	San Juan River at Shiprock, N. Mex	12,900	2,679	1,941,000	256	1,850	52	675,700
3795	San Juan River near Bluff, Utah	23,000	2,836	2,053,000	361	2,730	43	997,100
3800	Colorado River at Lees Ferry, Ariz	107,900	17,550	12,710,000	499	23,660	80	8,642,000
3820	Paria River at Lees Ferry, Ariz	1,570	31.9	23,110	1,090	94	22	34,300

[1] For water years 1939-57.
[2] For water years 1953-57.
[3] For water years 1938-42, 1947-57.
[4] For water years 1947-57.
[5] For water years 1951-55.

(after Iorns & others, 1965)

Source: Reference (43).

agriculture, trans-basin diversions, and additional storage and regulation.

To adequately measure impact of an oil shale mine or other installation, it will be necessary to install continuous recording stream flow stations that include a recording turbidity meter, water quality monitors to record temperature and specific conductance, and an automatic device to collect samples for chemical analysis, with control for variable sampling rates according to stream flow. In addition, an automatic sampler for suspended sediment would be required and rigged to collect one sample each day and be actuated when stage exceeds pre-determined levels so that extra samples of the peaks are obtained. Chemical quality samples collected by the automatic samplers, should be analyzed for calcium, magnesium, sodium, aluminum, silica, carbonate, gicargonate, dissolved-solids concentration, chloride, and total organic carbon (unfiltered samples). Other ions such as fluoride or boron should be determined periodically to establish transient concentrations. Sediment samples should be analyzed for concentration and for size where concentrations are sufficient to permit determination. Bed material samples should be collected for size analyses about twice a year. About once each month, the sampling sites should be sampled for macroinvertebrates and periphyton.

Data on chemical quality and sediment concentrations, combined with stream-flow data, will facilitate the computation of chemical and sediment loads that are entering and leaving the tracts. Not all of the increased load of dissolved salts and suspended sediments in the Upper Colorado River Basin will be attributable to the oil shale development, and therefore, monitoring should be started in advance of development in order to establish baseline conditions.

Monitoring of fish and wildlife populations and their habitat would need to be established on an annual basis. Monitoring would occur by plans tailored to each plant or animal species selected for study. Populations would be monitored through relative abundance indices, which would involve species specific sampling quadrants, pellet and dropping counts, observation periods, etc. Big game and wild horse populations would probably be monitored through a coordinated system of scheduled observation and counts of the animals themselves, droppings, and tracks.

Fish species abundance and population composition would be sampled at selected stations on the White and Green Rivers and selected at tributaries. Fish sampling would occur several times a year in order to deep track of seasonal population differences. These data would in turn be evaluated with the above-mentioned water quality data.

Information from these monitoring studies would be used to avoid or minimize development damage to fish and wildlife populations and their habitat and as a record upon which to base re-establishment of suitable wildlife food and cover.

5. Additional Environmental Studies

Although significant progress has been made in delineating and devising environmental control measures, additional research is required. Such work is being conducted by independent groups within the public and private sectors. In addition, some 50 representatives of local, state, Federal, and industry organizations have been asked by the state of Colorado to outline a broad course of additional studies for:

(1) revegetation and surface rehabilitation

(2) environmental inventory and impact

(3) water resource management

(4) regional development and land use planning

The details of these studies have been developed and agreement has been reached on joint participation in this three-quarters of a million dollar, 2-year effort. The results of this cooperative effort will be available to complement and demonstrate many of the concepts presented in this evaluation. The data from these studies would be available prior to development of either private or public lands.

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II. DESCRIPTION OF THE ENVIRONMENT

A. General Regional Description

Large areas in the States of Colorado, Utah, and Wyoming contain rich oil shale in the Green River Formation (See Figures II-1, II-2, II-3). These oil shales occur beneath 25,000 square miles (16 million acres) of land, of which about 17,000 square miles (11 million acres) are believed to contain oil shale of potential value for commercial development.

The oil-shale bearing rocks, named the Green River Formation for their exposures near the town of Green River, Wyoming underlie several broad areas of high plateaus, high plains, isolated mesas and broad topographic basins.

Other oil-shale deposits are widely distributed in other areas of the United States, (See Figure II-2) but individual deposits are lower grade, too small, or too inaccessible to be of current interest for development. The shale oil potential of these very low grade resources are summarized in Table 1 (U.S. Geological Survey Circular 523; U.S. Bureau of Mines Bulletin 650, p. 180-202).

1. Physiography

The oil shale areas of Colorado, Utah and Wyoming are in sparsely settled, semi-arid to arid country, at elevations of 5,000 to 10,000 feet above sea level. The region is part of the high Colorado Plateau Province of the Upper Colorado River Basin, and the high plains of the

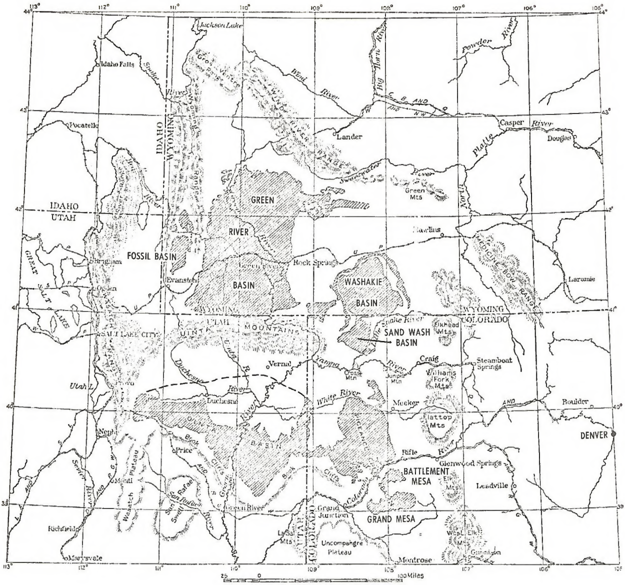
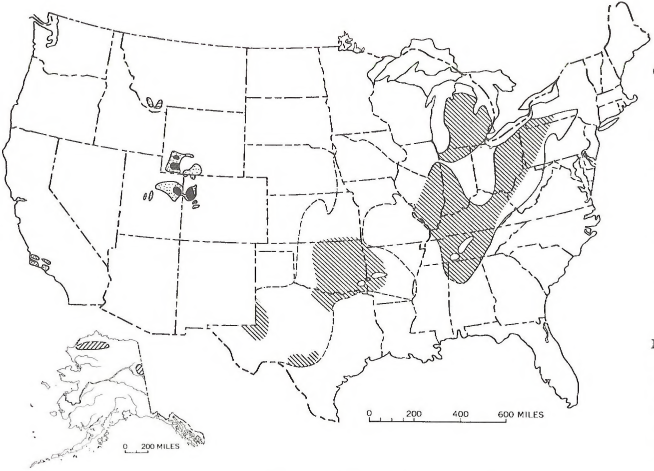


Figure II - 1. Distribution of the Principal Oil Shale-Bearing Areas of the Green River Formation (shaded areas) in Colorado, Utah and Wyoming.



EXPLANATION

Tertiary deposits
Green River Formation in Colorado, Utah, and Wyoming; Monterey Formation, California; middle Tertiary deposits in Montana. Black areas are known high-grade deposits

Mesozoic deposits
Marine shale in Alaska

Permian deposits
Phosphoria Formation, Montana

Devonian and Mississippian deposits (resource estimates included for hachured areas only in Geological Survey Circular 523). Boundary dashed where concealed or where location is uncertain.

Figure II-2. - Principal reported oil-shale deposits of the United States

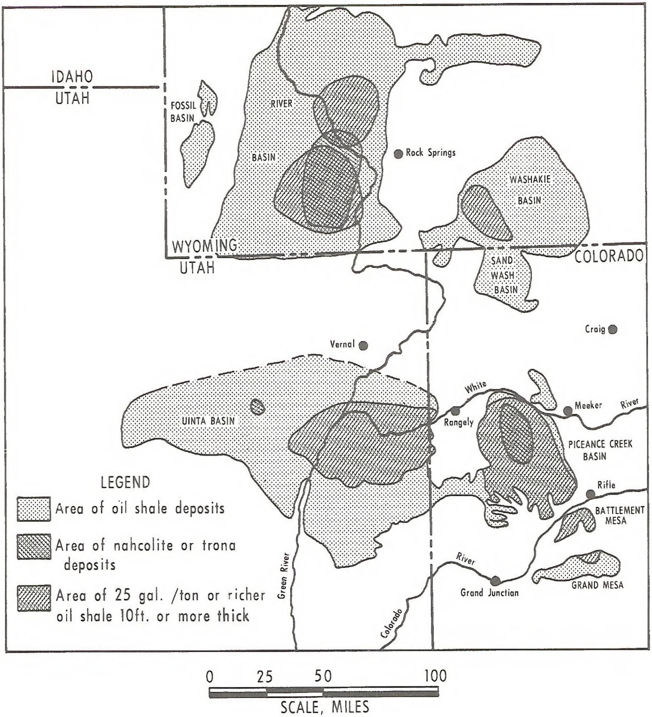


Figure II-3 Oil Shale areas in Colorado, Utah and Wyoming

Table II-1.—*Shale oil resources of the United States, in billions of barrels*

[ne, no estimate. Estimates and totals rounded]

Deposits	Known resources				Order of magnitude of possible extensions of known resources			Order of magnitude of undiscovered and unappraised resources			Order of magnitude of total resources		
	Recoverable under present conditions	Marginal and submarginal (oil equivalent in deposits)									Oil equivalent in deposits		
Range in grade (oil yield, in gallons per ton of shale)----------	~~10~~ 25–100	25–100	10–25	5–10	25–100	10–25	5–10	25–100	10–25	5–10	25–100	10–25	5–10
Green River Formation, Colorado, Utah, and Wyoming-----------	80	520	1,400	2,000	600	1,400	2,000	------	-----	------	1,200	2,800	4,000
Devonian and Mississippian shale, Central and Eastern United States ----------------------	None	None	200	200	None	800	1,800	------	-----	------	------	1,000	2,000
Marine shale, Alaska-----------	Small	Small	Small	Small	250	200	Large	------	-----	------	250	200	Large
Shale associated with coal ------	----do-------	--do--	ne	ne	Small	Large	--do--	60	250	210	60	250	210
Other shale deposits -----------	----do-------	--do--	Small	ne	ne	ne	ne	500	22,000	134,000	500	22,000	134,000
Total----------------------	80	520	1,600	2,200	850	2,400	3,800	550	22,000	134,000	2,000	26,000	140,000

(Source, U.S.G.S. Circular 523)

The oil shale resource estimates of this Table include shale zones of the Green River Formation 10 feet or more thick, yielding as little as 10 gallons of oil per ton. The resource estimates of the text are smaller. They include known shale units 15 feet or more thick, yielding 15 gallons or more oil per ton, the minimum thickness and grade used by the Geological Survey in classifying oil shale land in the Green River formation.

Wymoming Basin. The terrain varies from dissected, wooded, plateaus bounded by prominent oil shale cliffs, to sparsely vegetated plains, with low escarpments, commonly exposing the ledge and cliff forming oil shale. The region is drained by the Upper Basin tributaries of the Colorado River. Geologic uplift, stream erosion, and the varying degrees of resistance of the rock layers control the land forms.

The principal oil shale areas are in large topographic basins that are identified by streams draining most of the land surface. These include the Green River Basin and Washakie Basin in Wyoming, the Uinta Basin in Utah, and the Piceance Creek Basin in Colorado. Oil shale of possible commercial interest also underlies Battlement and Grand Mesas in Colorado.

Minor deposits also occur in the western escarpment of the Wasatch Plateau, and in the San Pitch Mountains bordering the Great Basin in Utah, in the Fossil Basin, Wyoming and in the Sand Wash Basin, Colorado.

2. Climate

The three-state oil shale area is a semi-arid and arid region. Annual precipitation varies from about 7 inches in the Wyoming Plains areas to 24 inches in the high plateau areas in Colorado. Much of the precipitation falls as snow during the December to April period. Summer thunder showers, with occasional flash floods sweep local areas.

Temperatures of the region are moderate during spring, summer and fall. Maximum temperatures in the lower elevations may reach 100 degrees F during mid-summer. Winter temperatures may drop to 40 degrees below zero. Frost free days vary from 50 in the higher elevation to 125 in lower elevations. The dry climate and short growing season has a limiting effect on agricultural use of the land.

Gentle westerly winds prevail in the broad plains of Wyoming Basin and Uinta Basin. Air movement patterns are irregular in the high plateau areas of Colorado and Utah. Strong thermal convection winds commonly occur during warm days along the Roan cliffs and adjacent divides, and strong turbulent winds may be associated with the thunder showers, but rarely with winter snow storms.

In the shallow valleys and low ridges of parts of the Uinta and Piceance Creek Basins there are no prevailing winds. A gentle air inversion is common at night in these areas. During summer months cool air flows down the valleys and warm air is displaced upward to the ridge crests.

3. Geology

The sedimentary rocks in and near the oil shale region comprise a rock sequence more than 26,000 feet thick in some areas. The oil shale bearing rocks of the Green River Formation (which ranges from 3000 to 7000 feet thick) are near the top of the rock column.

They are underlain by about 22,000 feet of older sediments that locally contain other minerals of potential commercial interest, principally oil and natural gas accumulations and coal. For the interested reader the following regional geologic reports describe the general geology, the oil and gas exploration and development, and other mineral resources of the region.

Exploration for oil and gas in Northwestern Colorado, 1962, Rocky Mountain Association of Geologists.

Guidebook to the Geology and Mineral Resources of the Uinta Basin, Utah's Hydrocarbon Storehouse, 1964, Intermountain Association of Petroleum Geologists.

Symposium on the Tertiary rocks of Wyoming, 1969, Wyoming Geological Association.

Upper Colorado Region, Comprehensive Framework Study, Appendix VII, Mineral Resources, 1971.

The region in which the Green River Formation was deposited was warped into large structural basins, and later elevated several thousand feet above sea level. The major streams and their tributaries traversing the region have eroded much of the sediments from these exhumed basins. The stream erosion has exposed the oil shale in cliff and ledges in many places. Gentle folds and minor faults locally deform the deposits but the sedimentary rocks of the oil shale areas as a whole are remarkably undisturbed structurally, except in the areas where the strata are steeply tilted on the flanks of the Uinta Mountains in Utah and Wyoming, and along the Grand Hogback in Colorado.

4. Mineral Resources

a. Oil Shales

The Green River Formation in the three-State region shown in Figure II-3 contains known oil shales with about 600 billion barrels of equivalent oil in the higher-grade deposits (averaging more than 25 gallons per ton and a minimum of 10 ft. in thickness). At a recovery of 50% of the richer deposits, which may be a high percentage, this is a significant potential energy resource. In lower grade oil shale zones of the Green River Formation (averaging 15 to 25 gallons per ton) there are an additional 1,200 billion barrels. The known parts of the oil shale deposits of the region contain a total of at least 1,800 billion barrels oil equivalent. Some 80% of the known higher grade reserves are located in Colorado, 15% in Utah, and 5% in Wyoming.

A recent review of these deposits by the National Petroleum Council (1972) indicated that shale of first interest for development (deposits 30 feet or more thick, yielding 30 gallons or more oil per ton, and less than 1500 feet below surface) contain about 130 billon barrels oil potential in place.

Colorado has the smallest geographical area of oil shale, but the richest, thickest, and best known deposits. In the Piceance Creek Basin the higher grade deposits (as previously defined) total some 480 billion barrels, in strata varying from 10 to 2,000 ft. in thickness, and with overburdens from zero to 1,600 ft. Substantial quantities of saline minerals are also present in the northern half of the Basin (see following section).

The largest oil shale-bearing area of the Green River Formation occurs in Utah. The richest shales occur in the east-central part of the Uinta Basin, at depths up to several thousand feet below the surface. These rich deposits total more than 80 million barrels.

Total known deposits of rich shales in Wyoming are estimated to be 30 billion barrels, the smallest of the rich deposits in the three states, and occur in the Green River Basin. Leaner shales exist over a wider area, including the Washakie Basin. The higher-grade shales in the Green River Basin are frequently associated with trona. Overburden ranges from 400 to 3,500 ft.

b. <u>Saline Minerals</u>

Sodium minerals have been discovered in association with certain deep shales of the Green River Formation, principally in the Piceance Creek Basin of northwestern Colorado. Trona (67 billion tons) and halite are associated with or adiacent to the shallow oil shales in the Green River Basin of Wyoming; however, the existence and/or extent of dawsonite and other saline minerals has not been established. In the Uinta Basin of Utah, the existence of sodium minerals has been shown in a few core holes, but again, the extent of these minerals has not been defined.

In Colorado's Piceance Creek Basin, dawsonite, nahcolite, and halite are intermixed or intermingled with oil shale in certain zones underlying the area. Three nahcolite strata are present near the base of the saline zone (Fig. II-4) and two halite-bearing strata exist in the upper part of the zone. The dawsonite, and other saline minerals, are finely disseminated in and associated with the oil shale in beds which are up to 700 ft. thick near the center of the Basin. Dawsonite (a dihydroxy sodium aluminum carbonate) is technically suitable for recovery of alumina by roasting and leaching.

c. Other Minerals

Within that portion of the upper Colorado region in Colorado, Utah, and Wyoming containing the Green River Formation oil shale, there are certain additional mineral deposits of significance. Among the more important of these are petroleum, natural gas, asphaltite, tar sands and coal.

The total potential crude oil reserves of the oil shale regions are approximately 680 million barrels. An additional 5 billion barrels are inferred to be present. Total natural gas resources are

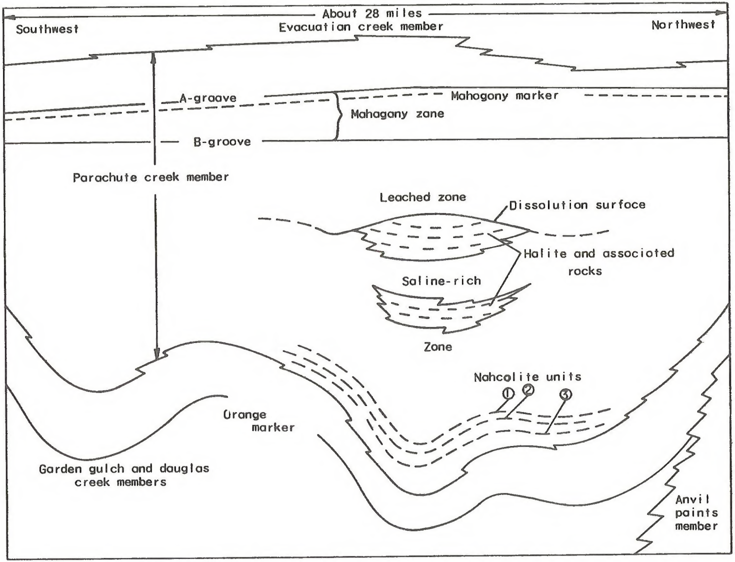


FIGURE II-4. - Diagrammatic Cross Section Showing ine Saline Rich Zones in the Oil-Shale-Bearing Rocks of the Piceance Creek Basin.

estimated to be of the order of 85 trillion cubic feet. An additional 300 trillion cubic feet may exist in tight formations from which the gas is not presently economically recoverable without the development of suitable techniques, which may include nuclear fracturing. (U.S. Atomic Energy Commission, 1972, Environmental Statement, Rio Blanco Gas Stimulation Project, Rio Blanco County, Colorado). Certain of these oil and gas fields lie in close proximity to the oil shale deposits. The sulfur content of both the crude oil and natural gas is believed to be too low to be commercially significant.

Gilsonite (asphaltite) deposits in proximity to the oil shales occur primarily in Uintah and Duchesne counties, Utah, where the total resource is estimated to be some 36-40 million tons. Bitumens in other rock asphalts occur in Carbon and Uintah counties (Utah), to the extent of over 7 billion equivalent barrels of oil.

Coal beds of present or future commercial value (15 to 30 inch minimum thickness) are exposed near the oil shale deposits. Beds of lesser thickness, or beds probably buried too deeply for commercial exploitation are even more extensive, and underlie much of the oil shale. The "indicated" coal reserves alone, in or adjacent to the oil shale regions of the three States, may be of the order of 6 - 8 billion tons, of which two-thirds are in Wyoming, and most of the remainder in Colorado.

The mineral resources of the Upper Colorado River Basin are summarized in a State-Federal Inter-Agency Group Comprehensive Framework Study. The report titled "Upper Colorado Region, Appendix VII Mineral Resources," (1971) includes maps of the oil shale deposits (Figure II-5) oil and gas fields (Figure II-6) coal deposits (Figure II-7) gilsonite and rock asphalt deposits (Figure II-8) in and near the oil shale region. The maps show the spatial relationship of the different mineral resources.

The previously discussed major saline minerals (dawsonite, halite, nahcolite, and trona) in or associated with the oil shales, and the crude oil, natural gas, bituminous rocks, and coal immediately adjacent to the shale deposits are believed to constitute the primary minerals of significant interest in connection with the study of the environmental impact of an oil shale industry. The existence of nearby gypsum deposits in Garfield County in Colorado and phosphate deposits in Wyoming and Utah are considered to be outside the area of interest of the present study. No commercial concentrations of other base or precious metals, or uranium, are known to be present in the oil shale area.

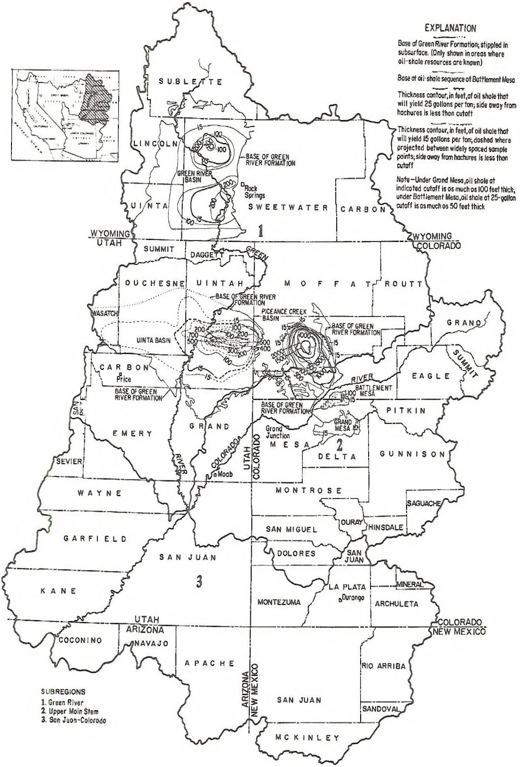


Figure II - 5 Oil shale deposits in Colorado, Utah, and Wyoming.

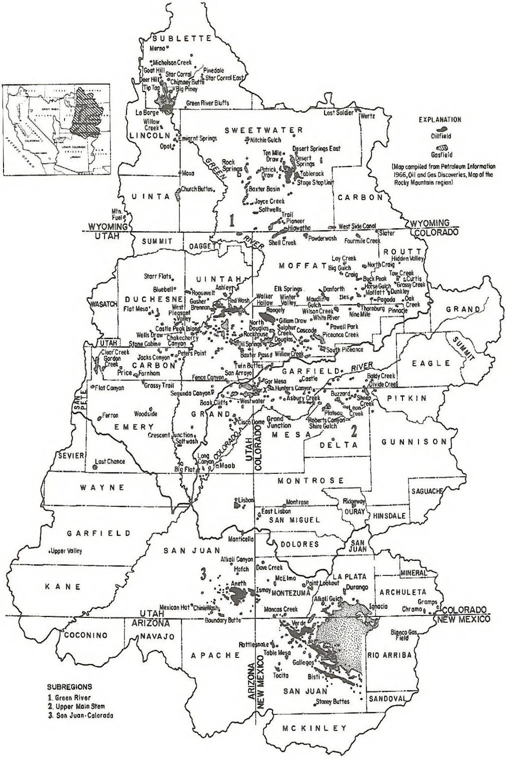


Figure II - 6 Oil and gas fields in the Upper Colorado Region.

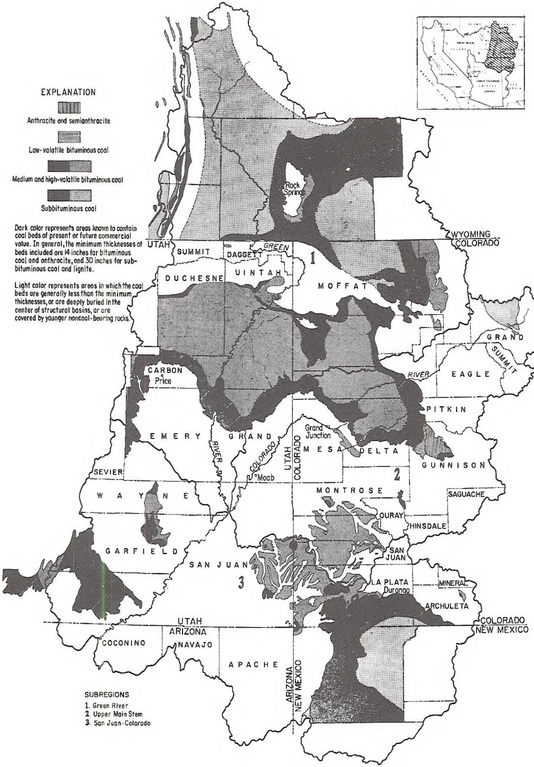


Figure II - 7 Coal deposits in the Upper Colorado Region.

Figure II - 8 Gilsonite and rock asphalt deposits and metalliferous district in the Upper Colorado Region.

5. Water Resources

The major water supplies of the oil shale region are the through-flowing rivers of the Upper Colorado River Basin. The larger rivers such as the Green, White, Yampa, and the main stem of the Colorado receive most of their water from the higher elevations adjacent to and upstream from the oil shale areas. The relatively lower oil shale areas receive from about 7 to 24 inches per year of precipitation and most streams are ephemeral. The runoff from the shale areas is fully committed for agricultural use and stock watering supplies. Local supplies of ground water occur in the oil shale areas. The yield of wells in the areas generally will be small or moderate except where large drawdowns are possible or are required to maintain a dry mine. The chemical quality of the ground water differs from place to place and is different at different depths. The larger withdrawals of ground water probably will be (sooner or later) salty.

a. Surface Water

The surface water resources of the Upper Colorado River Basin have been the subject of many comprehensive investigations because of the long debates among the Lower Basin States and between the Lower and Upper Basin States. Iorns and others (1964) published all the basic data for the Upper basin that was collected from 1892 to 1957. Interpretations of the data were published in a companion publication in 1965 (Iorns and others, 1965). Basic data on discharge and quality of streams in the Upper Basin are published annually for each State by the U.S. Geological Survey. The quality of water in the Colorado River is assessed biannually by the Secretary of the Interior at the direction of Congress (U.S. Department of Interior, 1971). The Bureau of Reclamation [1/] estimated that up to 5.8 million acre-feet per year are available for Upper Basin depletion (i.e. consumption). This assumes that the Upper Colorado River Basin States are to supply one-half of the Mexican Water treaty obligation or 750,000 acre-feet per year.

The following table (Table 2) is a summary of estimates made by the Bureau of Reclamation and shows the amount of water available for potential development after accounting for present use and presently committed future uses.

The Colorado River Basin Project Act, (Public Law 90-537, 90th Congress S.1004, September 30, 1968,) recognized the need for augmenting the water supply of the Colorado River. Under title II, Section 202, the Congress declared that the satisfaction of the requirements of the Mexican Water Treaty from the Colorado River constituted a national obligation which shall be the first

1/ Hearings before the subcommittee on Irrigation and Reclamation of the Committee on Interior and Insular Affairs, House of Representatives, 90th Congress, 2nd Session, on H.R. 3300 and S.1004, January 30, 1968, page 751.

Table 2.--Present and Future Water Use in the Upper Colorado River Basin (thousand acre-feet annually).

	Colorado	Utah	Wyoming
Allocated share of 5,750,000 acre feet 1/	2,976	1,322	805
Present use (1970)	-1,796	- 684	-304
Committed future use	- 947	- 397	-377
Evaporation from storage units	- 342	- 152	- 92
Credit for water salvage	+ 121	+ 18	+ 31
Not identified	12	107	38
Committed future use that could be made available for oil shale	147 2/	---	19 3/
Total potential water that could be made available for depletion for oil shale development 4/	159	107	57

1/ Arizona received the right to the consumptive use of the first 50,000 acre-feet per year.

2/ From the existing Green Mountain and Ruedi Reservoirs and the authorized West Divide Project.

3/ From the existing Fontenelle Reservoir - Seeskadee Project.

4/ This includes water not presently identified for a particular use plus water from authorized projects committed to oil-shale development and water from existing reservoirs not presently committed to a particular use. Additional water can be made available if the States permit the industry to purchase some of the water rights from those presently using water and if the use-category is changed from some of the future commitments.

obligation of any water augmentation project. When such an augmentation project is in operation the Upper Colorado River Basin States would be allowed to use an additional 750,000 acre-feet of water per year. This would provide an additional 388,000 acre-feet of water per year for potential use in the State of Colorado. It would also make an additional 172,000 acre-feet available for use in Utah and 105,000 acre-feet in Wyoming. This augmentation might be made by weather modification, desalting, or other measures.

After augmenting the Colorado River for the full amount of the Mexican Treaty, the total amount of water in acre-feet that could be made available for potential future use in Colorado, Utah and Wyoming without changing designated present and future use-categories are summarized as follows:

Colorado	Utah	Wyoming
547,000	279,000	162,000

Water quality of major streams generally is quite good. Average dissolved-solids concentrations generally are less than 700 mg/l, but during periods of low flow they can exceed 2,000 mg/l.

b. <u>Ground Water</u>

Ground water resources within the oil shale areas are less well-known than the surface-water resources but are believed to be of significant quantities only within the Piceance Creek Basin, Colorado. Coffin and others (1971) estimated that about 2.5 million acre-feet of water is stored in the Green River Formation of the Piceance Creek Basin. Table II-3 summarizes the water-bearing characteristics of the geologic units in the Piceance Creek Basin. Welder and McGreevey (1966) report that some ground water is available in the Washakie Basin but they show very few data. Feltis (1966) in his report on water in the Colorado Plateau of Utah found data on only a few stock wells in the Utah oil shale area.

Generally, ground water occurs in the alluvium associated with the streams in the oil shale areas, bu the alluvium has very limited extent and thickness. Withdrawals of ground water from the alluvium in large quantities would either quickly dry up the alluvium or would induce water from a stream which would be subject to prior appropriation.

Good quality ground water occurs in much of the alluvium and in the recharge areas of the bedrock aquifers. However, large withdrawals of ground water from the bedrock, eventually will cause large declines in water level, induce saline water to move towards the withdrawal points, and intercept water that is moving toward the streams.

6. Wildlife and Fishery Resources

The oil shale region provides a variety of combinations of vegetative, climatic, physiographic, and cultural conditions, which results in several ecological systems that are attractive to

Table II-3–SUMMARY OF GEOLOGIC UNITS AND THEIR WATER-BEARING CHARACTERISTICS

System	Series	Geologic unit		Thickness (feet)	Physical character	Water quality	Hydrologic character
Quaternary	Holocene and Pleistocene(?)	Alluvium		0–140	Sand, gravel, and clay partly fill major valleys as much as 140 feet; generally less than half a mile wide. Beds of clay may be as thick as 70 feet; generally thickest near the center of valleys. Sand and gravel contain stringers of clay near mouths of small tributaries to major streams.	Near the headwaters of the major streams, dissolved-solids concentrations range from 250 to 700 mg/l. Dominant ions in the water ara generally calcium, magnesium, and bicarbonate. In most of the area, dissolvad solids range trom 700 to as much as 25,000 mg/l. Abova 3,000 mg/l the dominant ions ara sodium and bicarbonate.	Water is under artesian pressure where sand and gravel are overlain by beds of clay. Reported yields as much as 1,500 gpm. Well yields will decrease with time because valleys are narrow and the vallay walls act as relatively impermeable boundaries. Transmissivity ranges from 20,000 to 150,000 gpd per ft. The storage coefficient averages 0.20.
Tertiary	Eocene	Green River Formation	Evacuation Creek Member	0–1,250	Intertonguing and gradational beds of sandstone, siltstone, and marlstone; contains pyroclastic rocks and a faw conglomerate lansas. Forms surface rock over most of the araa; thins aporaciably westward.	Water ranges from 250 to 1,800 mg/l dissolvad solids.	Beds of sandstone are predominantly fine grained and have low permeability. Water movas primarily through fractures. The part of the member higher than valley floors is mostly drained. Reported to yiald as much as 100 gpm where tested in tha north-central part of the basin. Member has not been thoroughly tested, and larger yields may be possibla.
			Parachute Craek Member	500–1,800	Kerogenaceous dolomitic marlstona (oil shale) and shale; contains thin pyroclastic beds; fractured to depths of at laast 1,800 feet. Abundant saline minerals in deeper part of the basin. The member can be dividad into three zones—high resistivity, low rasistivity or leached, and Mahogany (oldest to youngest), which can ba correlated throughout basin by use of geophysical logs.	Water ranges in dissolved-solids content from 250 to about 63,000 mg/l. Below 500 mg/l, calcium is the dominant cation; above 500 mg/l, sodium is generally dominent. Bicarbonate is generally the dominant anion regardlass of concentration. Fluoride ranges from 0.0 to 54 mg/l.	High resistivity zona and Mahogany zone are relatively impermeable. The leached zone (middle unit) contains water in solution openings and is under sufficient artesian pressure to cause flowing wells. Transmissivity ranges from less than 3,000 gpd per ft in the margins of the basin to 20,000 gpd per ft in the center of the basin. Estimated yields as much as 1,000 gpm. Total water in storage in leached zone 2.5 million acre-feet, or more.
			Garden Gulch Member	0–900	Papary and flaky marlstona and shale; contains some hads of oil shale and, locally, thin beds of sandstone.	One water analysis indicates dissolved-solids concentration of 12,000 mg/l.	Relatively impermeable and probably contains few fractures. Prevents downward movement of water. In the Parachute and Roan Creeks drainages, springs ara found along contact with overlying rocks. Not known to yiald water to wells.
			Douglas Creek Member	0–800	Sandstone, shale, and limestona; contains oölites and ostracods.	The few analyses availabla indicate that dissolved-solids content ranges from 3,000 to 12,000 mg/l. Dominant ions ara sodium and bicarbonate, or sodium and chlorida.	Ralatively low permaability and probably littla fractured. Maximum yield is unknown, but probably less than 50 gpm.
			Anvil Points Mamber	0–1,870	Shale, sandstone, and marlstone grade within a short distance westward into the Douglas Creek, Garden Gulch, and lower part of the Parachute Creek Member. Beds of sandstona are fina grained.	The principal ions in the water are generally magnesium and sulfate. The dissolved-solids content ranges from about 1,200 to 1,800 mg/l.	Sandstone beds have low permeability. A few wells tapping sandstone beds yield less than 10 gpm. Springs issuing from fractures yield as much as 100 gpm.
		Wasatch Formation		300–5,000	Clay, shale, lenticular sandstona; locally, bads of conglomarata and limastone. Beds of clay and shala ara tha main constituanta of tha formation. Containa gypsum.	Gypaum contributas sulfata to both surfaca-watar and ground-water suppliaa.	Bads of clay and shale ara ralatively impermeabla. Bads of sandstona ara poorly parmaabla. Not known to yiald water to walla.

wildlife. The mule deer is regarded as the most important big game species. (Figure II-9). As many as 19,000 deer have been harvested during a single hunting season. The region also has a sizeable population of antelope (Figure II-10) and provides habitat for limited numbers of elk, bear, mountain lion, and moose. In addition, the region supports 3 species of small game, 27 species of migratory waterfowl and shorebirds, and 6 species of upland game birds, 5 species of furbearers, 21 species of non-game mammals, 200 species of non-game birds, and 24 species of raptors. Several wild horse herds range over the area.

The sport fishery resources of this semi-arid region are quite limited; however, most of the available habitat supports various non-game species. The major game fish resources are in the Colorado, Green and White Rivers. Several streams particularly the headwaters support native populations of cutthroat trout as well as rainbow and brown trout. Trout fishing in these headwater areas and isolated beaver dams is the major type of angling in the oil shale areas. Little systematic investigation of the Colorado River Basin fishes has taken place since 1900, and the status of many species is not known. Existing information indicates that the region has retained a large number of native species unique to this area. Several of these may soon be classified as rare or endangered.

Figure II - 9 Key Habitat for Mule Deer in the Upper Colorado Region

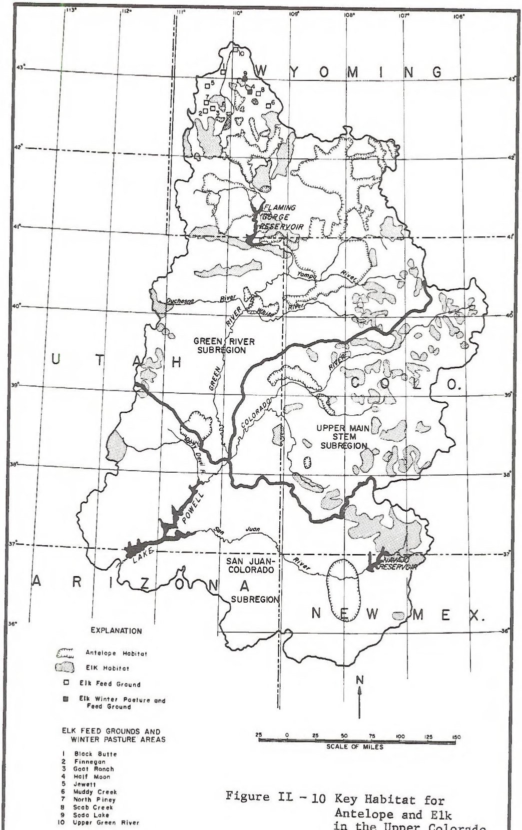


Figure II - 10 Key Habitat for Antelope and Elk in the Upper Colorado Region

An exception to the generally limited fish resources within the oil shale areas are the important fish populations of the Green River including the Flaming Gorge Reservoir in Wyoming and the Colorado and White Rivers in Utah and Colorado.

The fish and wildlife of the Upper Colorado River Region outside of the better oil shale lands are varied and include many game species, and others.

Fishable waters of the Upper Colorado Region include more than 36,000 acres in natural lakes, 275,000 acres in impoundments, and 9,000 miles of fishing streams. (See table II-4 and Figure II-11) The cold water fishing in the high elevation streams and lakes attracts particularly the sports fishermen. Most of all of the fishable waters are outside the oil shale area.

Table II-3. - Inventory of Fishable Waters Existing in 1965

Upper Colorado Region

Item	Streams (Miles)	Natural Lakes (Acres)	Impoundments (Acres)	Farm Pond (Acres)
Coldwater				
Colorado	4,715	11,209	33,548	618
Utah	1,344	8,988	37,822	160
Wyoming	1,527	17,486	56,238	24
Warmwater				
Colorado	660	0	916	0
Utah	706	0	153,850	38
Wyoming	Insig.	0	0	0

There are hundreds of miles of such high-quality trout streams, some of the more outstanding of which are listed below. Excluded from this list are stream segments that are subject to damage from the construction of authorized projects.

Figure II-11. - Fish Installation and Facilities Existing in 1965 for the Upper Colorado Region.

Green River Subregion

Colorado:

Green River - Utah State line to mouth of Yampa River

Yampa River - source to Craig, Colorado

White River - North and South Forks from source to Buford, Colorado

Utah:

Green River - Flaming Gorge Dam to Colorado State line

Blacks Fork - source to Wyoming State line

West Fork Smith Fork - source to Wyoming State line

Henry's Fork - source to Wyoming State line

Willow Creek - source to Wyoming State line

Beaver Creek - source to Wyoming State line

West Fork Beaver Creek - source to Wyoming State line

Burnt Fork - source to Wyoming State line

Birch Creek - source to Flaming Gorge Reservoir

Willow Creek - source to Green River

Wyoming:

Green River - source to Big Sandy River excluding Fontenelle Reservoir

New Fork River - source to Green River

Hams Fork - source to Kemmerer, Wyoming

Upper Main Stem Subregion

Colorado:

Colorado River - source to Williams Fork River near Parshall except for Shadow Mountain-Lake Granby Reservoir complex

Tonahutu Creek - source to Colorado River

Willow Creek - source to Willow Creek Reservoir

Fraser River - source to Colorado River

Vasquez Creek - source to Fraser River

St. Louis Creek - source to Fraser River

Williams Fork River - except for Williams Fork Reservoir

Blue River - except for Green Mountain and Dillon Reservoirs

Piney Creek - source to Colorado Rivdr

Eagle River - above Fall Creek (Gilman)

Eagle River - Gore Creek to mouth

Homestake Creek - source to Eagle River

Roaring Fork River - source to Colorado River

Hunter Creek - source to Roaring Fork River

Castle Creek - source to Roaring Fork River

Maroon Creek - source to Roaring Fork River

Snowmass Creek - source to Roaring Fork River

Fryingpan River - source to Basalt except for Ruedi Reservoir

Crystal River - source to Roaring Fork River

Gunnison River - source to Blue Mesa Reservoir plus adjoining tributaries

North Fork Gunnison River - Paonia Dam to mouth

Dolores River - source to Dove Creek

San Miguel River - mouth of Lake Fork to mouth of Horsefly Creek

Utah:

La Sal Creek - source to Colorado State Line

Game birds of the region include principally sage grouse, pheasant, chukar partridge, and numerous species of water fowl. Their principal habitats are shown in Figures II-12 and II-13)

A number of big game species including moose, bighorn sheep (see Figure II-14), and Elk (Figure II-10) are mostly commonly found in those habitats peripheral to the proposed oil shale development sites.

7. Soils and Plant Life

Soils of the Green River oil shale region vary widely. (Figure II-15) Most of the wider stream valleys contain alluvium with well developed soil that supports good agricultural growth if there is sufficient stream flow for irrigation. The slopes and many upland areas commonly expose bare rock cliffs and ledges with little or no soil development. Other gently sloping upland areas contain thin poorly developed soil and locally thicker alluvial soil.

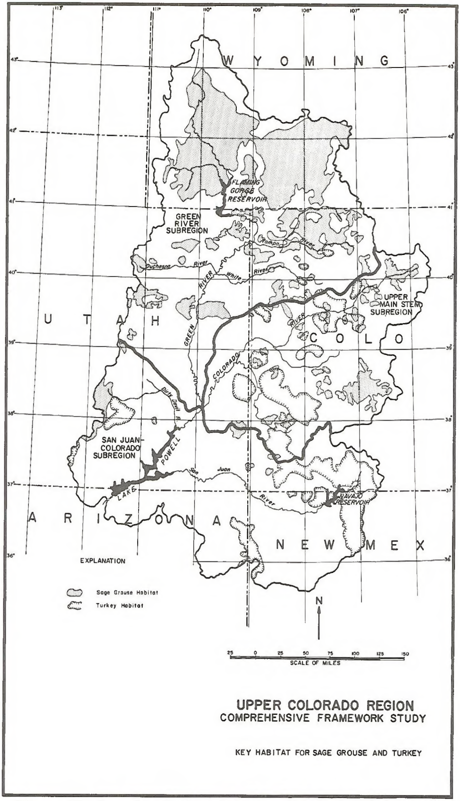


Figure II-12. - Key Habitat for Sage Grouse and Turkey in the Upper Colorado Region.

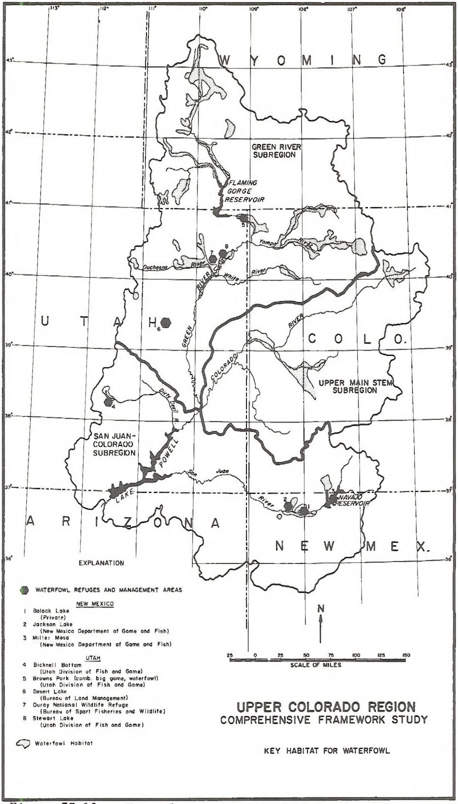


Figure II-13. - Key Habitat for Waterfowl in the Upper Colorado Region.

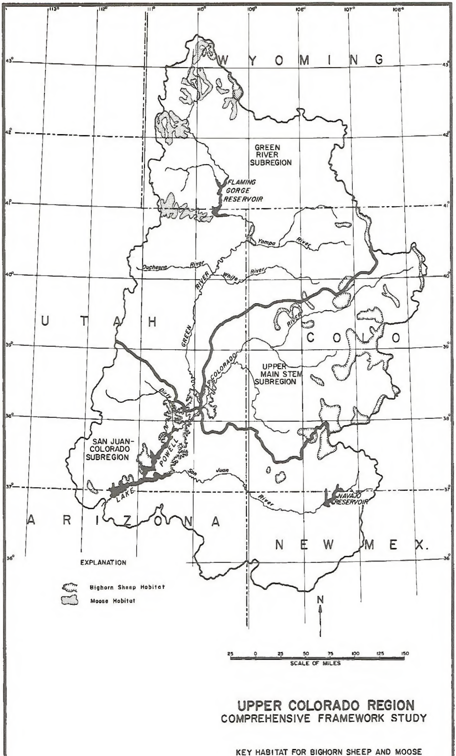
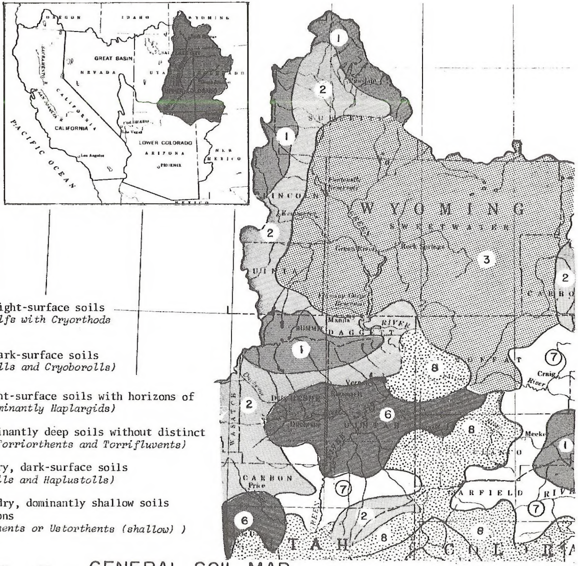


Figure II-14. - Key Habitat for Bighorn Sheep and Moose in the Upper Colorado Region.



LEGEND

1 Cool, usually moist, light-surface soils *(Dominantly Cryoboralfs with Cryorthods or Cryochrepts)*

2 Cool, usually moist, dark-surface soils *(Dominantly Argiborolls and Cryoborolls)*

3 Warm, usually dry, light-surface soils with horizons of clay accumulation *(Dominantly Haplargids)*

6 Warm, usually dry, dominantly deep soils without distinct horizons *(Dominantly Torriorthents and Torrifluvents)*

7 Warm, intermittently dry, dark-surface soils *(Dominantly Argiustolls and Haplustolls)*

8 Warm or cool, usually dry, dominantly shallow soils without distinct horizons *(Dominantly Torriorthents or Ustorthents (shallow))*

4 Warm, usually dry, light-surface soils with horizons of calcium carbonate or gypsum accumulation *(Dominantly Calciorthids)*

5 Warm, usually dry, light-surface soils with weakly developed horizons *(Dominantly Camborthids)*

Figure II - 15 - GENERAL SOIL MAP

Adapted by Land Use and Management Work Group From National Atlas Soils Compiled by the Soil Conservation Service and Published by U.S.D.I. Geological Survey 1969

25 0 25 50 75 100 125 150 MILES

In the high arid plains areas of Southwestern Wyoming, generally, thin soil is developed on the more prominant land features. Alluvial soil may be developed in valleys and swales.

Information on the soils of the oil shale region of Colorado, Utah, and Wyoming is limited to that generally derived from "Soil Association" type of surveys. A soil association consists of two or more soils which occur in a particular geographic area and in a repeating pattern. Each soil within an association has a characteristic type of profile and landscape of a known extent.

The soils information presented in this report was gleaned from several reports developed primarily by the Soil Conservation Service, United States Department of Agriculture. The soils maps shown in Figure II-15 is based on work done by SCS.

Vegetation resources of the region are principally regimens of grass land, sage brush, grease wood-salt bush, mountain shrub, and juniper-pinon. Locally some playa lake areas are covered by a salt pan where no vegetation grows. The vegetation retards soil erosion and serves as livestock and game forage and shelter. On the higher ground of the Roan Plateau in Colorado and Utah there are restricted areas of douglas fir and aspen forest growth.

8. Aesthetic Resources

The oil shale region is outlined by noteworthy oil shale cliffs along parts of the Piceance Creek and Uinta Basins in

Colorado and Utah and by less noteworthy bluffs and escarpments in the Wyoming Basins. Some picturesque canyon lands are developed where the Green and White Rivers cut through the oil shale basins in Utah and Wyoming. The Flaming Gorge Reservoir is a varied setting. For the most part, however, the terrain within the oil shale basins offers a gently rolling hill or flat plain view that has attracted little attention aesthetically.

9. Recreational Resources

The environs adjacent to but outside of the oil shale lands contain many prime outdoor recreational opportunities. Boating and fishing are popular along the Flaming Gorge Reservoir in Wyoming, Desolation Canyon and White River in Utah. Huntinh, fishing and sightseeing are also among the activities which are quite popular in these open public lands. However, the oil shale lands are located a good distance from the lakes and streams and therefore are not heavily utilized for water-oriented activities. However, there is some hunting of deer, antelope and game birds within the oil shale region itself.

The public lands provide the high quality of outdoor recreational activities. Some of the opportunities which are available on these lands are of the following types:

(a) Water oriented activities associated with the lakes and streams of the high country and along the major streams of the low-lands-Duchesne, Green, and White Rivers and especially the Flaming Gorge National Recreation Area;

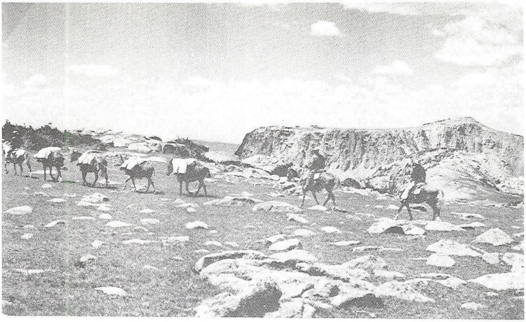
(b) Wildlife opportunities, especially those associated with Wildlife Refuges, hunting mule deer, elk, moose and bighorn sheep at the higher elevations on National Forest and Bureau of Land Management Lands;

(c) Sightseeing the unique features and scenic wonders of Flaming Gorge National Recreation Area, Dinosuar National Monument, Ouray Wildlife Range, Whiterocks Fish Hatchery, Desolation Canyon and many more;

(d) Hiking and rockhounding in the backcountry of Yellowstone creek, Rock Creek, the badlands in the White River area, Piceance Creek, etc; and

(e) Visting the Historic areas of Old Fort Duchesne, the Uintah-Ouray Indian Reservation, Wind River Shoshone and Commanche Country, Freemont Indian Culture, etc.

The Upper Colorado River Region, which encompasses the Green River oil shale areas, also includes many prime recreational opportunities in areas near the oil shale lands. (see Figures II-16, II-17, and II-18). These are described in the recreation report of the Upper

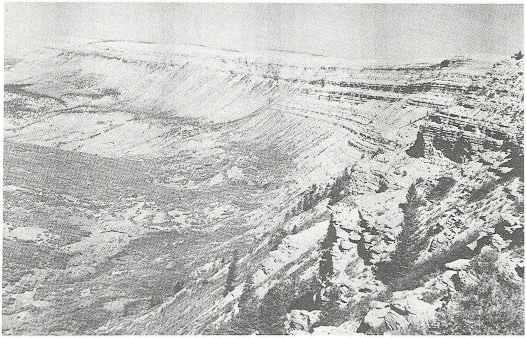


Pack trip excursion, Primitive areas of the region.

Sailing, Flaming Gorge Reservoir, Utah.

Figure II - 16 Recreational opportunities in the Upper Colorado Region

Fishing on Trappers Lake, White River Forest, Garfield County, Colorado.



Cathedral Bluffs, on the West rim of Piceance Creek Basin, Colorado. The prominant oil shale cliffs, sit above the talus slopes, and hummocky landslide ground below.

Figure II - 17 Recreation and scenery in the Upper Colorado Region

Winter snowmobiling, a popular recent outdoor activity of the Upper Colorado River region.

Antelope Flat Public Campground, Flaming Gorge Reservoir.

Figure II - 18 Recreation in the Upper Colorado Region

Colorado Region Comprehensive framework study (1971). Many of the prime scenic areas are in the National Mounments, National Recreational areas, National Forests, including Wilderness areas, ski areas, public camp sires. Many of the larger towns near the oil shale lands have municipal or public golf courses, swimming pools, rodeo grounds, playgrounds and other recreational facilities.

One common characteristic of all the recreation areas on the public lands of the oil shale region is that they have few developed urban-type facilities which may be expected by in coming populations. The region as a whole, however, does have many untapped recreation opportunities, such as described above, within as well as outside the primary oil shale lands of Colorado, Utah, and Wyoming.

10. Socio-Economic Resources

The tri-state oil shale region of Wyoming, Colorado and Utah is sparsely populated and relatively isolated. The total population of the area under consideration was approximately 119,400 in 1970.

Population shifts during the 1960-1970 period, in the seven principal counties involved in oil shale development of the region were as follows:

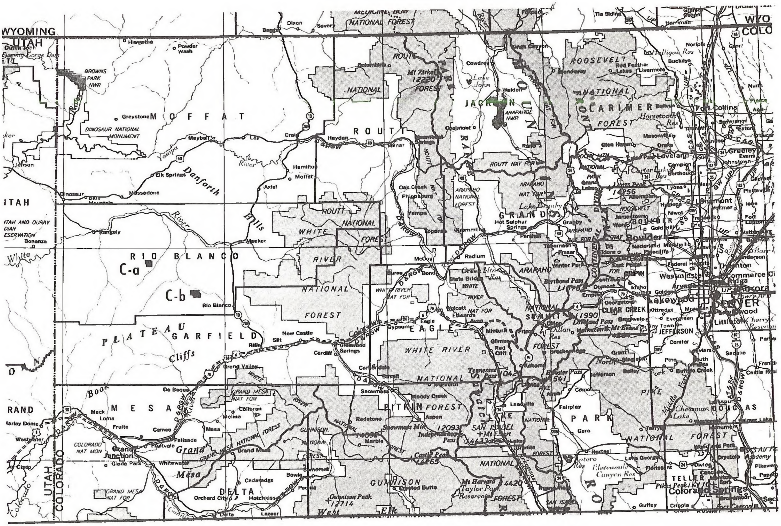
	Population	
	1960	1970
Colorado		
Garfield	12,000	14,800
Mesa County	50,700	54,300
Rio Blanco County	5,200	4,800
Utah		
Duchesne County	7,200	7,300
Uintah County	11,600	12,700
Wyoming		
Sweetwater County	18,000	18,400
Uinta County	7,500	7,100
Totals	112,200	119,400

Source: U.S. Department of Commerce, Bureau of Census.

The average population density of the area as a whole is approximately three people per square mile. Although there are a number of small air fields located in the area, only one (in Grand Junction, Colorado) has large jet transport capabilities. All others are serviced by connecting flights to such major metropolitan areas as Denver and Salt Lake City, which are more than 200 miles from the oil shale region.

The major communities in or adjacent to the area are Grand Junction, Colorado, south of the Piceane Creek Basin (population 20,000), Rifle and Craig, also in Colorado; Vernal, Utah, 40 miles northeast of the selected area (population, 4,000); and Rock Springs (population 11,700) and Green River, Wyoming. (See Figures, II-19, II-20 and II-21).

The area is primarily dependent upon agricultural activities, the minerals industry, and tourist and recreation for its economic support. Much of the farm land is used by ranchers for cattle and sheep. Mining activities in the area include oil and gas, limited uranium and vanadium production in Colorado and Utah, and oil, natural gas, sodium (trona) and coal production in Wyoming. The value of farm products sold annually is $37.2 million. The value of mineral products is $136.6 million annually for the total area.



Albers Equal Area Projection

SCALE 1:2,000,000

MILES: 10 0 20 40 60 80 100

KILOMETERS: 10 0 50 100 150

Figure II - 19 Map of northwestern Colorado showing environs of nominated oil shale lease tracts

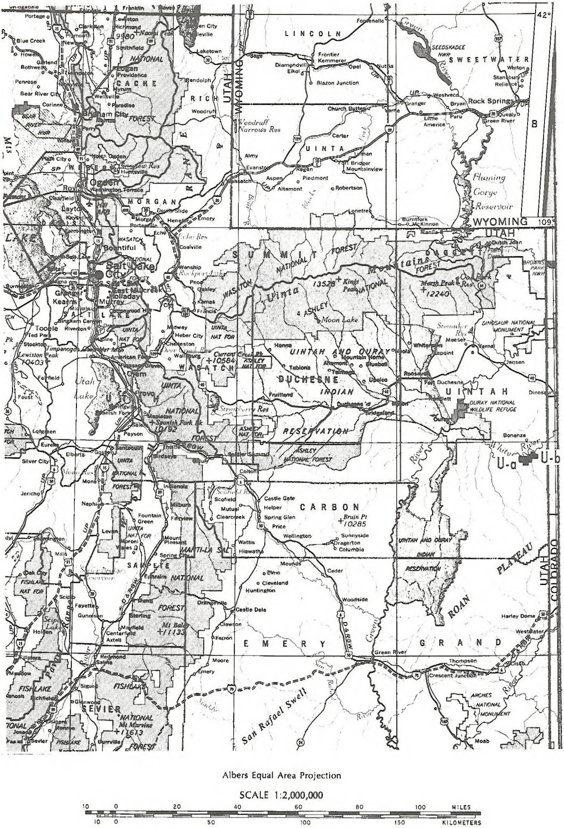
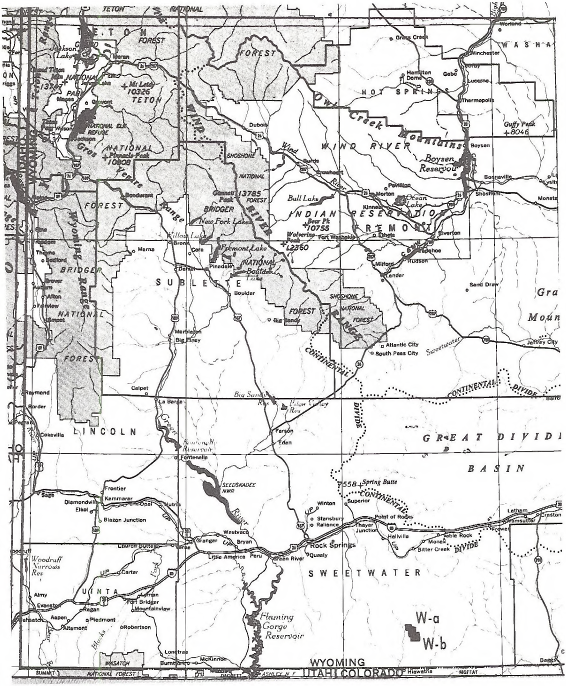


Figure II - 20 Map of Northwestern Utah showing Environs of nominated Lease Tracts



Albers Equal Area Projection

SCALE 1:2,000,000

10 0 20 40 60 80 100 MILES

10 0 50 100 150 KILOMETERS

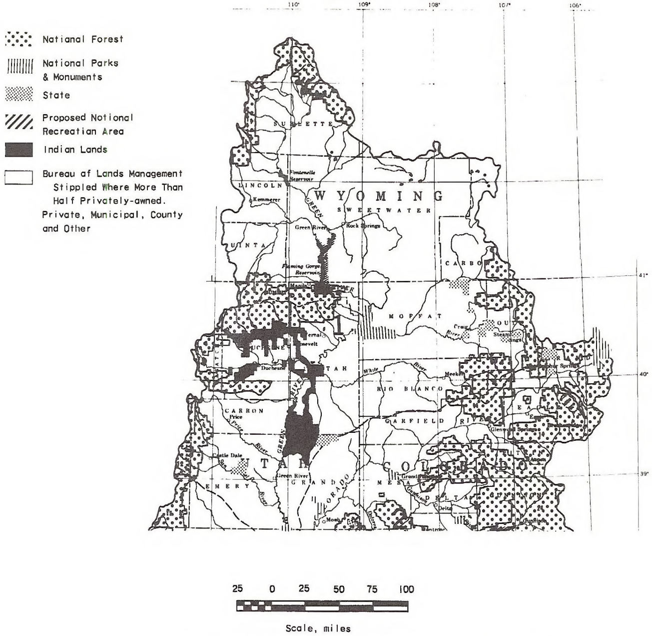
Figure II - 21 Map of Southwestern Wyoming showing Environs of nominated Lease Tracts

11. Ownership

The ownership of major land areas of the oil shale region is shown in Figure II-22. Of the more than 11 million acres of oil shale land potentially suitable for commercial development in Colorado, Utah and Wyoming, about 72 percent are public lands, administered by the Department of the Interior, these public lands contain 80 percent of the high-grade oil shale.

The areas shown on Figure II-22 as public lands supervised by the Bureau of Land Management include some privately-owned land, some with minerals reserved to the United States. Most of the oil shale land has been claimed at one time or another by individuals or companies for placer claims, with oil shale, aluminum or other prospectively recoverable mineral designated as valuable. Efforts to clarify the validity of these claims have been vigorously persued by the Interior Department since 1965, and ownership of land and mineral for numerous claims have been resolved. The land status of the Federal Oil Shale Lands in Colorado, Utah and Wyoming in 1968 is summarized in the Tables II-5, II-6, and II-7, and is described in greater detail in "Prospects for Oil Shale Development, Colorado, Utah and Wyoming," 1968, U.S. Department of the Interior.

Much of the Federal oil shale land is under lease for oil and gas exploration, other areas are leased for sodium mineral extraction or sodium prospecting permits. The same lands may be leased for



LAND OWNERSHIP STATUS OF UPPER COLORADO REGION, 1965

Figure II - 22 Map showing land ownership status for the Upper Colorado Region

Table II-5. - Federal oil-shale lands
(including both clear and clouded title)

Item	Colorado	Utah	Wyoming	Total
Quantity of land				
Total oil-shale land, thousand acres	1,800	4,900	4,300	11,000
Federal oil-shale land, thousand acres 1/	1,420	3,780	2,670	7,870
Percent Federal land (of total)	79	77	62	72
Percent distribution, Federal land	16	45	39	100
Quality of Federal oil-shale lands				
Low grade or unappraised:				
Acres, thousand	570	2,130	1,500	4,200
Percent distribution	13	51	36	100
At least 15 ft of 15-25 gpt 2/ shale:				
Acres, thousand	300	1,070	700	2,070
Percent distribution	15	51	34	100
At least 10 ft of over 25 gpt shale:				
Acres, thousand	600	600	400	1,600
Percent distribution	37	37	26	100
Quantity of shale oil in place - Federal lands 3/				
At least 15 ft. of 15-25 gpt shale:				
Shale oil, billion barrels	600	150	150	900
Percent distribution	66	17	17	100
At least 10 ft of over 25 gpt shale:				
Shale oil, billion barrels	390	70	20	480
Percent distribution	81	15	4	100
Total:				
Shale oil, billion barrels	990	220	170	1,380
Percent distribution	72	16	12	100

1/ Largely clouded by unpatented mining claims.
2/ Gallons per ton.
3/ Data include some allocations from unappraised lands.

Table II-6. - Non-Federal oil-shale lands - clear title 1/

Item	Colorado	Utah	Wyoming	Total
Quantity of land				
Total oil-shale land, thousand acres	1,800	4,900	4,300	11,000
Private oil-shale land, thousand acres	400	1,100	1,600	3,100
Percent private land (of total)	21	23	38	28
Percent distribution, non-Federal land	13	35	52	100
Quality of private oil-shale lands				
Low grade or unappraised:				
Acres, thousand	165	640	890	1,695
Percent distribution	10	38	52	100
At least 15 ft of 15-25 gpt 2/ shale:				
Acres, thousand	80	320	440	840
Percent distribution	10	38	52	100
At least 10 ft of over 25 gpt shale:				
Acres, thousand	170	170	260	600
Percent distribution	28	28	44	100
Quantity of shale oil in place--private lands				
At least 15 ft of 15-25 gpt shale:				
Shale oil, billion barrels	130	40	80	250
Percent distribution	52	16	32	100
At least 10 ft of over 25 gpt shale:				
Shale oil, billion barrels	80	20	10	110
Percent distribution	73	18	9	100
Total:				
Shale oil, billion barrels	210	60	90	360
Percent distribution	58	17	25	100

1/ Indian and State lands are included in data shown.
2/ Gallons per ton.

Table II-7 - Federal oil-shale lands - clouded title

Item	Colorado	Utah	Wyoming	Total
Quantity of land				
Total Federal lands, thousand acres	1,420	3,780	2,670	7,870
Land with unpatented mining claims:				
Old claims, prior to 1966, thousand acres	400	2,600	2,200	5,200
New claims, 1966, thousand acres	700	400	400	1,500
Total with claims, thousand acres	1,100	3,000	2,600	6,700
Percent of Federal land with claims	78 1/	79	97	85
Quality of lands with unpatented claims				
Low grade or unappraised:				
Acres, thousand	-500	1,700	1,400	3,600
Percent distribution	14	47	39	100
At least 15 ft of 15-25 gpt 2/ shale:				
Acres, thousand	200	800	700	1,700
Percent distribution	12	47	41	100
At least 10 ft of over 25 gpt shale:				
Acres, thousand	500	500	400	1,400
Percent distribution	36	36	28	100
Quantity shale oil in place, unpatented mining claims 3/				
At least 15 ft of 15-25 gpt shale:				
Shale oil, billion barrels	500	100	100	700
Percent distribution	72	14	14	100
At least 10 ft of over 25 gpt shale:				
Shale oil, billion barrels	320	50	20	390
Percent distribution	82	13	5	100
Total:				
Shale oil, billion barrels	820	150	120	1,090
Percent distribution	75	14	11	100

1/ Ninety-five percent of lands in Piceance Creek Basin, Colorado, have unpatented mining claims.
2/ Gallons per ton.
3/ Data include some allocations from unappraised lands.

livestock grazing. Some accomodation between different leases will be required when the oil shale is developed.

B. Colorado (Piceance Creek Basin)

1. Physiography

The term "Piceance Creek Basin" is sometimes used to describe a major geologic structural and sedimentary basin in Rio Blanco, Garfield and Mesa Counties, Colorado. (Figure II-1, II-3.) The portion of the Basin containing the principal oil shale deposits is a dissected plateau, known as the Roan Plateau, bounded by steep escarpments which face the Colorado River on the south, the White River on the north, the valleys of Government and Sheep Creek on the east, and Douglas Creek on the west.

Piceance Creek, Yellow Creek and tributaries of Douglas and Sheep Creeks drain the northern part of the oil shale area and are tributaries to the White River. Parachute Creek and Roan Creek drain the southern part of the oil shale area, into the Colorado River. Most of the Federal oil shale lands are located in the stream drainage basin of Piceance Creek and Yellow Creek. Smaller deposits, in Battlement and Grand Mesas south of the Colorado River, are excluded from consideration here.

The topography of the shale bearing area is somewhat unique. The differential resistance to erosion has produced ridges and valleys with local relief of 200 to 600 feet. They are generally oriented north and north-easterly in a nearly parallel pattern as illustrated in the aerial view, Figure II-23. Elevation varies from about 5,250 feet along the White River to a maximum of about 9,000 feet for some ridge crests on the south.

2. Climate

Annual precipitation in the Piceance Basin varies from approximately 12 inches in the extreme northwest corner to approximately 24 inches in the southwest corner. The area is generally classified as semi-arid.

Slightly less than half of the precipitation occurs as snow during the months of December to April. The spring precipitation is usually very small. During the latter part of the summer occasional thunderstorms, with accompanying flash floods, ranging from light to very severe occur throughout the area. Fall weather can vary from fair to infrequent rain or snow storms.

The area is subject to thermal extremes, with summer temperatures reaching 100 degrees Fahrenheit and winter temperatures dropping to 40 degrees Fahrenheit below zero.

The frost-free season varies from 124 days at the lower elevations to 50 days at upper elevations. The dry climate and relatively short growing season permit restricted growth of small quantities of irrigated native hay, corn for silage, and some small grains along

Figure II - 23 Aerial View Colorado Oil Shale Country in the Central Part of the Piceance Creek Basin

Piceance Creek, Yellow Creek, and the White River.

3. Geology

The geology of oil-shale-bearing rocks of the Piceance Creek Basin, Colorado, has been described by Donnell (1961), in a report titled "Tertiary Geology and Oil-Shale Resources of the Piceance Creek Basin--Northwestern Colorado." U.S. Geological Survey Bulletin 1082-L. The reader is referred to his report for maps showing the detail of distribution of oil shale and associated rocks of the Green River Formation.

The principal oil shale unit known as the Parachute Creek Member of the Green River Formation forms the upper part of a cliff or escarpment 2000 to 3500 feet high around the margins of the basin. The upper part of the oil shale sequence is exposed in some deep gulches within the basin behind the escarpment. In the interior of the basin, however, the oil shale is concealed in most places by a buff-weathering sandstone and siltstone sequence known as the Evacuation Creek Member.

The general distribution of oil shale, and saline minerals in or associated therewith, in the Piceance Creek Basin is illustrated in the cross section of Figure II-24 and II-25.

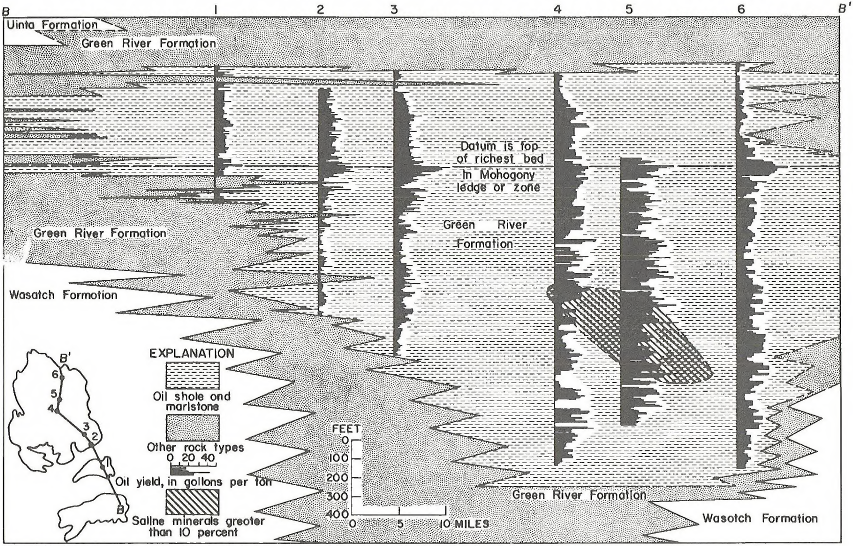


Figure II - 24 Cross Section of the Green River Formation in the Peceance Creek Basin

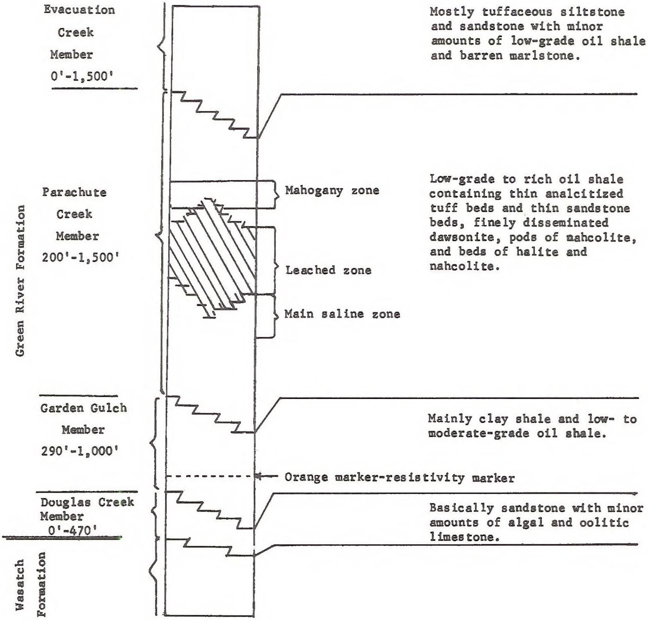


Figure II - 25 Generalized Section of the Green River Formation in the Piceance Creek Basin

a. Stratigraphy

The Green River Formation in most of the Piceance Creek Basin is divided into four members (Figure II-25).

Evacuation Creek Member--The Evacuation Creek Member, the uppermost rock unit, is the surface rock that covers much of the basin. It ranges in thickness from 0 feet to 1,500 feet and consists in great part of sandstone and tuffaceous silstone with minor amounts of marlstone and low-grade oil shale.

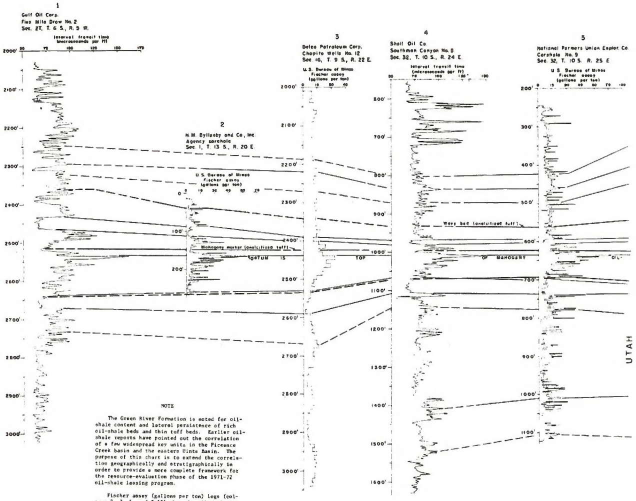
Parachute Creek Member--The parachute creek member ranges in thickness from 200 feet near the margin of the basin to more than 1,500 feet near the geographic and depositional center of the basin. The Parachute Creek contains most of the rich oil shales in the Green River Formation. Two main oil-shale zones contain all of the oil shale of economic interest.

Upper oil-shale zone--The upper oil-shale zone encompasses that part of the section from base of the Evacuation Creek Member to the base of the Mahogany Zone (Figures 1 and 2). Its thickness ranges from a few feet near the margin of the basin to more than 500 feet near the Anvil Points mine a few miles west of Rifle.

Lower oil-shale zone--A thin zone of low-grade oil shale, barren marlstone, sandstone, or siltstone separates the upper and lower oil shale zones. The lower zone ranges in thickness from a wedge edge at the margin of the basin, to more than 1,000 feet at or near the depositional center of the basin. Where best developed the lower oil-shale zone may be divided into a number of sub-zones numbered R-1 to R-6, from bottom to top. (see Figure II-26)

Leached zone--In a large area encompassing several hundreds of square miles saline minerals originally deposited in or with the oil shale have now been taken into solution by ground water and saline water now occupies the voids created by leaching. This unit, known as the leached zone, is hundreds of feet thick in places. The top and base are extremely irregular and generally extend from the lower part of the Mahogany zone downward into the lower zone (Figure 2). Saline minerals have also been leached from oil shale units above the Mahogany zone.

Garden Gulch Member--The Garden Gulch member ranges in thickness from 290 feet near the center of the basin to more than 1,000 feet a few miles north and west of Rifle. It consists mainly of clay shale. The upper part intertongues with the lower part of the lower oil-shale zone in the Parachute Creek Member. In the Garden Gulch Member the orange marker, a distinctive kick on the resistivity log of wells drilled through the Green River Formation, in general marks the base of oil shale of economic interest.



NOTE

The Green River Formation is noted for oil-shale content and lateral persistence of rich oil-shale beds and thin tuff beds. Earlier oil-shale reports have pointed out the correlation of a few widespread key units in the Piceance Creek basin and the eastern Uinta Basin. The purpose of this chart is to extend the correlation geographically and stratigraphically in order to provide a more complete framework for the resource-evaluation phase of the 1971-72 oil-shale leasing program.

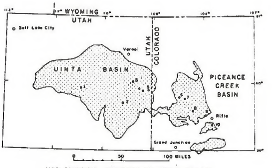
Fischer assay (gallons per ton) logs (columns 2, 3, 5, and 7-10) show the oil-shale sequence in drill holes where reliable data have been collected. Mechanical logs are shown for the remaining drill holes. Sonic logs (columns 1 and 4) and a density log (column 6) are also shown because their configurations correspond closely with shale-oil content.

Some names used here for key beds and rich oil-shale zones have been used in earlier oil-shale reports; others are used for the first time. The R-4 and R-6 zone designations have been used earlier (Donnell and Blair, 1970); the R-2, R-3, and R-5 zones are newly designated here.

SELECTED REFERENCES

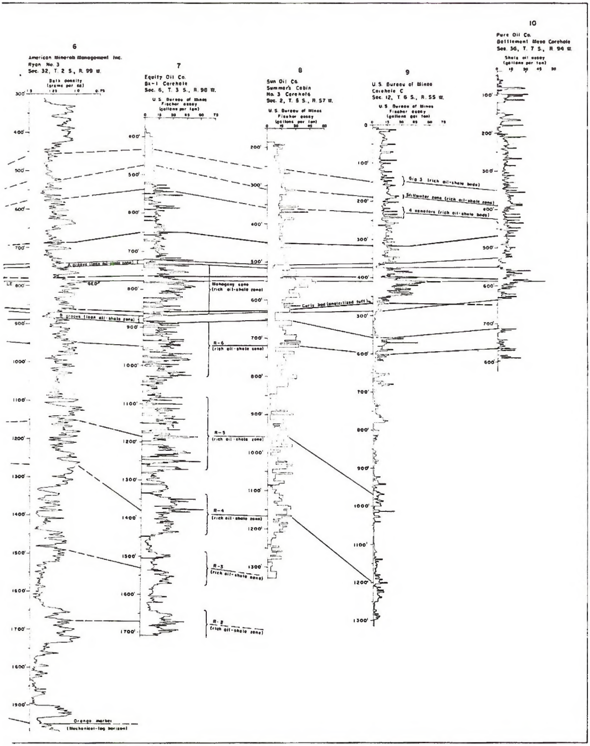
Curry, R. O., 1964, Oil-content correlation of Green River oil shales, Uinta and Piceance Creek Basins, *in* Intermtn. Assoc. Petroleum Geologists Guidebook 13th Ann. Field Conf., Uinta Basin, 1964: p. 169-171.

Donnell, J. R., and Blair, R. W., Jr., 1970, Resource appraisal of three rich oil-shale zones in the Green River Formation, Piceance Creek Basin, Colorado: Colorado School Mines Quart., v. 65, no. 4, p. 73-87.



MAP SHOWING LOCATION OF DRILL HOLES

Figure II - 26 Chart showing correlation of several key units in the Organic-Rich sequence of the Green River formation (continued II - 62)



For sale by U.S. Geological Survey, price 50 cents

Figure II - 26 (continued)

Douglas Creek Member--The Douglas Creek Member ranges in thickness from 0 feet to 470 feet. It consists mainly of sandstone, with minor amounts of algal, olitic, and ostracodal limestone and in places low-grade oil shale.

b. Structure

Folds--The Piceance Creek Basin is a large syncline with a structural relief of almost 4,000 feet in the area north of the Colorado River. The main synclinal configuration is modified by several rather large substructures, among them the Piceance Creek dome in the northeastern part of the basin; and the east end of the Rangely anticline that trends southeast in the northwest part of the basin.

Faults--A number of northwest trending high-angle normal faults cut the Green River Formation. The faults frequently form the walls of grabens with the downdropped block containing numerous minor faults with small displacements. The maximum vertical displacement on any fault rarely exceeds 200 feet.

Joints--Most of the streams west of Piceance Creek that are tributary to Piceance and Yellow Creeks have a pronounced alinements to the northeast. Many side gulches trend northwest, at right angles to the major stream drainages. These alinements coincide with the trend of the major joint systems. The joint systems are readily mappable along the outcrop of the oil shale. The joints are well-developed in the brittle marlstone and low-grade oil shale but are more poorly developed, in most places, in the less brittle Mahogany ledge and some of the rich lower oil-shale zones. The joint systems sometime provide avenues for ground-water movement in the Evacuation Creek and Parachute Creek members.

4. Mineral Resources

a. Oil Shale

In-place oil-shale resources in the Piceance Creek Basin, in zones thicker than 15 feet that average 15 or more gallons of oil per ton, total about 1-1/4 trillion barrels of oil. Of this total, about 600 billion barrels are contained in shale averaging 25 or more gallons per ton and 450 billion barrels in shale averaging 30 or more gallons per ton. In the center of the basin the oil-shale sequence is about 2,000 feet thick and individual beds about a foot thick range in value from a few gallons to as much as 90 gallons per ton.

b. Nahcolite

Nahcolite is sodium bicarbonate mineral (NaHCO3) that occurs throughout the major part of the Parachute Creek Member. It may be present as elliptical pods that in some places are as much as several feet in diameter, or it may be present as beds that are as thick as 10 or 12 feet. In all parts of the upper oil-shale zone, nahcolite probably averages less than 5 percent by weight, but in thick sequences of the lower oil-shale zone nacholite may average more than 30 percent by weight. Near the center of the basin where the deposits of nahcolite are best developed, resources of as much as 0.3 billion tons of nahcolite per square mile are indicated (Dyni, 1971). Figure II-27, shows the thickness of the nahcolite-bearing oil shale in the northern part of the Piceance Creek basin in Colorado. Nahcolite is a potential source of soda ash and may also be useful for removal of sulfur from industrial stack gases.

c. Dawsonite

Dawsonite is a dihydroxy sodium aluminum carbonate mineral ($NaAl(OH)_2CO3$) that occurs finely disseminated in the oil shale mainly in the lower oil-shale zone in the part of the Piceance Creek basin that is in Rio Blanco County. Alumina may be relatively easily extracted from dawsonite; therefore, although the percent of alumina in dawsonite is small, it may be of economic interest. A sequence of oil shale as thick as 800 feet near the center of the basin contains dawsonite in appreciable quantities. Units of mineable thickness may contain 3 percent by weight of equivalent extractable alumina. Figure II-28 shows the thickness of the dawsonite-bearing oil shale in the northern part of the Piceance Creek Basin in Colorado.

d. Halite

An area of approximately 75 square miles in the north-central part of the basin is underlain by halite. Where it is well-developed, the zone containing halite is more than 300 feet thick and has individual halite beds as thick as 30 feet. The halite beds

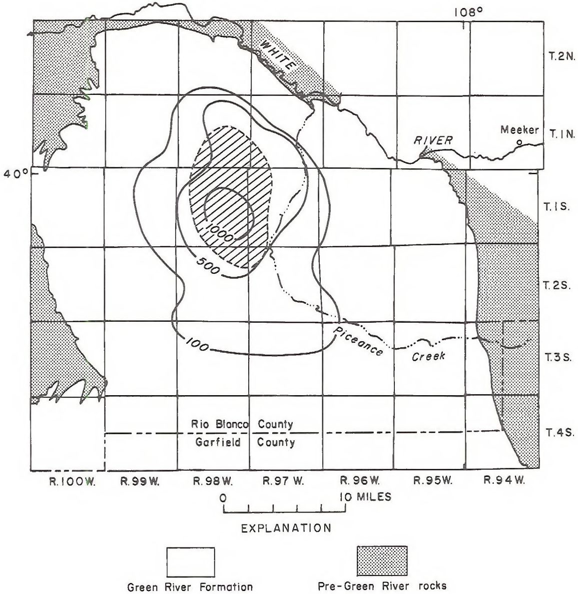


Figure II - 27 Thickness of nahcolite-bearing oil shale in the northern part of the Piceance Creek Basin

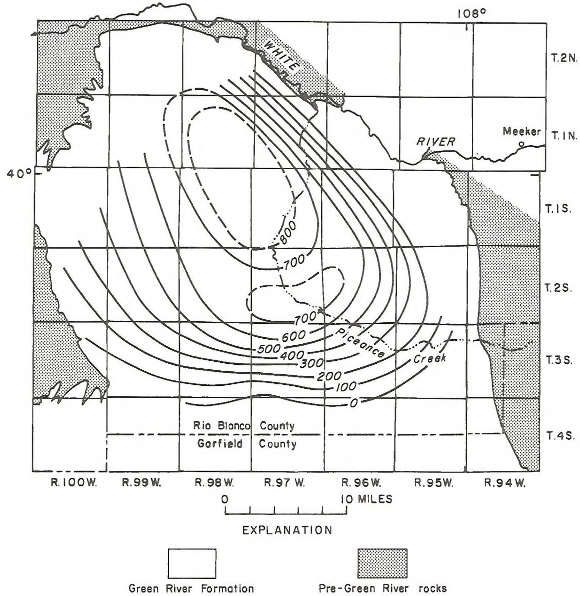


Figure II - 28 Thickness of dawsonite-bearing oil shale in the northern part of Piceance Creek Basin, Colorado.

are large units barren of organic matter, in R-5 one of the richer parts of the lower oil-shale zone.

e. Natural Gas

Natural gas is produced from the Piceance Dome in the northeastern part of the Piceance Basin. The upper most productive zone is in the basal sandstone of the Green River Formation. Other productive sandstones as much as 6,000 feet below the Green River Formation are known.

In other parts of the Piceance Creek Basin, gas-bearing sandstones have been encountered in many exploration wells, but the wells have been shut-in due to limited production potential.

5. Water Resources

Water resources within the Piceance Creek Basin are described by Coffin and others (1968 and 1971), and are summarized in two recent reports on mineral development of the basin (Colorado Governor's Oil Shale Advisory Committee, p. 31-42; and U. S. Atomic Energy Commission, 1971, p. A15-A27).

a. Surface Water

Surface-water supplies in the basin are small and completely developed. A supply of surface water large enough for mines and retorting plants is not present in the streams in the Piceance Creek basin. Direct flow of the streams in the basin is over-appropriated. Water for a 1,000,000 bbl/day shale oil industry must be imported from the White and Colorado Rivers in order to obtain a full supply.

Direct flow of the White River is inadequate several months of the year to supply all of the applications for appropriation that have been filed with the State Engineer. Water could be available for purchase from proposed public and private projects on the White River and the Yampa River. The proposed Yellow Jacket and Rio Blanco or Sweetbridr projects could yield as much as 165,000 acre-feet per year when and if completed.

Colorado River water is available for purchase from the Bureau of Reclamation's Green Mountain and Ruedi reservoirs. A possible future source of water could be the authorized "West Divide Reclamation Project". Cost of Colorado River water in 1971 was from $10 to $40 per acre-foot at the releasing reservoir. Purchaser would pick up the water from the main channel of the river (minus conveyance loss) and lift it to the point of use which will increase the cost. More than 200,000 acre-feet per year might be developed in the Colorado River above DeBewue, for use in the Piceance area.

The following Table shows the dissolved solids content of the White River at high and low flows. In general, the quality of the White River is excellent.

Table II-8 --Flows and Total Dissolved Solids Concentrations White River, Colorado. (Data from Federal Water Pollution Control Administration, 1966.)

	Sampling	Number of Samples	Mean* TDS mg/l	Extreme TDS-mg/l	Average Flow cfs	Extreme Flow cfs
White River at USGS	5- 8-62	25	162	255	286	1,210
Gage near Buford, Colorado	9- 3-64			104		110
South Fork White River	2-15-64	7	144	195	189	560
at USGS Gage at Buford, Colo.	2- 3-64			107		85
White River at USGS	5- 8-62	26	344	689	600	2,620
Gage below Meeker, Colo.	9- 2-64			189		250

* Flow weighted mean.

The quality of the Colorado River above the Cameo gaging station is also excellent. The Department of Interior Progress Report No. 5 (1971, p.105) shows that 2,439,000 acre-feet of water passed the station near Cameo, Colorado, in 1968 and had an average dissolved solids content of 439 mg/l. The average annual flow near Cameo between 1941 and 1968 was 2,758,000 acre-feet having an average dissolved solids content of 406 mg/l.

b. Ground Water

The Green River Formation is the most widely available source of ground water in the Piceance Creek basin of Colorado. The Parachute Creek and Evacuation Creek Members of the Green River Formation contain water under artesian pressure in most of the area. Wells tapping the Evacuation Creek Member yield from a few gallons per minute to as much as 200 gpm. Wells tapping the Parachute Creek Member, the principal aquifer, may yield as much as 1,000 gpm. The transmissivity of the Parachute Creek Member ranges from less than 3,000 gallons per day per foot to more than 20,000 gpd per ft. This member contains 2.5 million acre-feet or more of water in storage but the quantity of water that can be feasibly recovered is probably a small fraction of the total. The dissolved-solids concentration of water in the Green River Formation ranges from 250 to more than 60,000 mg/l.

Alluvium is a source of ground water in the major stream valleys although the areal extent of the alluvium is small compared to that of the bedrock aquifer. Initially, wells tapping the alluvium might yield as much as 2,000 gpm but would quickly deplete streamflow and decline in yield. The dissolved-solids concentration of water in the alluvium ranges from 250 to 25,000 mg/l.

6. Wildlife and Fish Resources

The 805,000-acre Piceance Creek basin constitutes Colorado's most important mule deer range. It supports a resident population and is the principal wintering ground for the migratory White River herd. Colorado's 605,000-acre Game Management Unit 22 which lies within the basin had an annual average harvest of 6,000 deer during the period 1960-69. The present population is estimated to be between 24,000 to 35,000 animals, which is 15% to 20% of the state's deer population. A herd of 100-200 elk inhabit the area, using it more in winter than in summer. Though not abundant, black bears exist throughout the area. A small band of Rocky Mountain Sheep and a small herd of bison have been introduced by the Colorado Game, Fish and Parks Department.

Mountain lions are regarded as scarce, and it is estimated that possibly 15 of these animals live within the Piceance Creek Basin. Abundance and location of this species have been shown to coincide with deer numbers and movements.

Approximately 50 wild horses exist in the basin. They are protected from hunting and trapping and are considered aesthetically valuable.

Small mammal species are widely distributed, and possible densities of cottontail and snowshoe hare are 150-200/sq. mile and 125/sq. mile, respectively. Sage grouse, blue grouse, and ring-necked pheasants are present in small, isolated populations. Sage grouse are the most abundant, approaching a fall density of 10 birds/sq. mile in acceptable habitat.

7. Soils

Soils of the Piceance Creek Basin vary from very thin or none on the steep slopes and cliffs to thick alluvial soils on the wider valley floors. Upland areas may be covered by thin soils or high level thick alluvial soil.

The alluvial valley land supports good hay crops where irrigated, otherwise sagebrush or greasewood. The upland alluvium supports sagebrush predominantly, with some grass. The thin upland soils generally support Pinon-Juniper.

A technical discussion of the Piceance Creek Basin soils follows:

Soils of the Piceance Creek basin consist primarily of Haplorthents, Haplargids, Argiustolls and the Haplustolls on the uplands. Many of these soils are lithic or shallow to bedrock. Deep alluvial soils such as Haplustolls, Haplaquolls occur in valley bottoms and drainage-ways. Land types such as rock outcrops, rough gullied land and shale badlands occur as small areas throughout the Basin. The west slope of Cathedral Bluffs is an example of the Outcrop land type.

A generalized map of the soils of the White River Basin Colorado which includes the Piceance Creek Basin is shown in Figure II-29. Soils contained within the Piceance Creek Basin are described below.

Soil Mapping Unit 3: <u>Shallow rocky and deep moderately dark colored soils of the uplands</u>

Landscape: The landscape is highly dissected by creeks and their intermittent tributaries. There is a repeating pattern of narrow alluvial valleys along creeks flanked by canyons or very steep rocky slopes which rise to higher lying uplands. Narrow bands of rolling upland or mesas form divides between upper reaches of creek tributaries.

Slopes: Slope gradients usually range between 10 and 60 percent. Those of less than 10 percent are confined to alluvial valleys, mesas and uplands.

Climate: For the most part elevations range between 6,000 and 7,000 feet. Climate is more favorable for plant growth than in the desert areas around Rangley. Annual precipitation is 12 to 15 inches and mean annual temperature is a little less than 47 degrees F. The frost-free period is about 100 days.

Soil parent materials: Soil parent materials are mainly limy sandstones and shales along with reworked valley fill derived from sandstone and shale. Much of the fill materials is stony and gravelly. Eolian deposits mantle portions of the rolling upland between the creeks. Recent alluvium

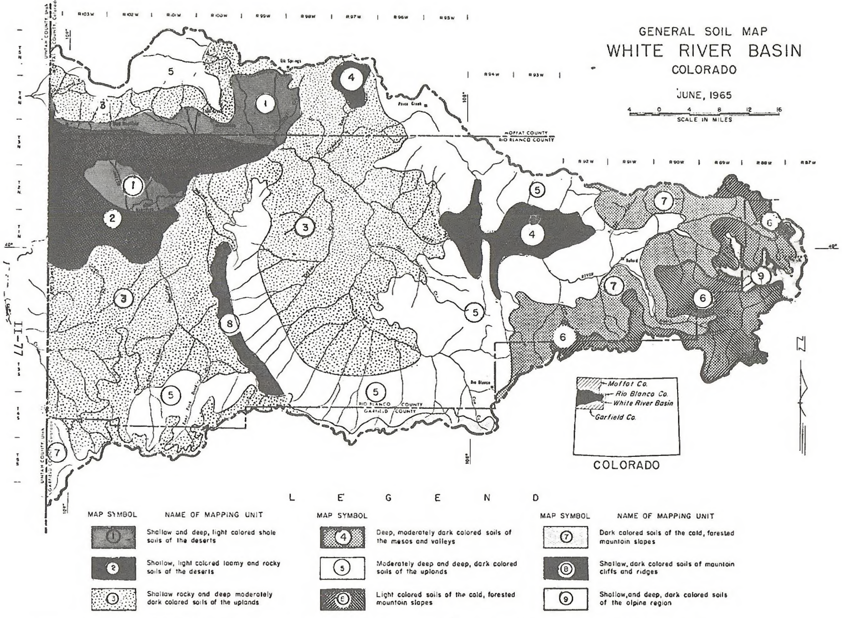


Figure II - 29 General soil map of the White River Basin is of minor extent. Alluvial valleys have been markedly influenced at many places by sediments and colluvium from nearby slopes.

Composition of map unit 3 by Great Soil Groups, except for Regosols included with the Brown soils and land types, is estimated as follows:

Percent	1949 Great Soil Group	1965 Great Group, Subgroup or Family
60	Lithosols	Haplorthents (Lithic and Thin)
25	Brown soils	Haplargids and Camborthids
5	Alluvial soils	Haplorthents
2	Solonetz soils	Natrargids
8	Land types (Rock outcrop 3%) (Rough gullied land 3%) (Shale badlands 2%)	Land types (Rock outcrop 3%) (Rough gullied land 3%) (Shale badlands 2%)

One of the most extensive components of unit 3 is the light colored, shallow, stony soils that are intermingled with large sandstone boulders and rock outcrops. They overlie sandstone or shale at depths of less than 20 inches, and are usually calcareous. Stony soils are extensive near narrow valleys and canyons that dissect the unit. At many locations soft sandstone is penetrated by tree roots. Closely associated with rocky soils are deeper soils with weak horizonation that have high proportions of coarse fragments in the subsoil. Deeper soils are in footslope positions below and within the complex patterns of shallow soils.

Medium depth soils occupy lower portions of many narrow mesa divides. They have formed in local wind deposited sandy materials derived for the most part from sandstone. Deep, moderately dark colored loamy soils which are noncalcareous to depths of 6 to 24 inches occupy smoother slopes on the divides. Often they have formed in calcareous wind-blown deposits of loamy texture.

Accelerated erosion is chiefly confined to rolling upland divides and stream valleys. Water erosion on rocky, gravelly pinyon-juniper slopes is principally along roads and hunting trails. Trails and roads along steep upper slopes have had a striking effect in concentrating runoff water. Deep gullying and destructive bank cutting is visible along all intermittent creeks and head cutting is common on side drains. Summer storms frequently wash out many bridges and creek crossings within this unit. Detrimental flood deposits are left on alluvial fans and bottomlands which formerly supported good stands of grass.

Soil Mapping Unit 5: Moderately deep and deep, dark colored soils of the uplands.

Landscape: The unit consists of steep lower mountain slopes of rugged relief dissected by narrow valleys and streams. The sharp ridges of the Grand Hogback are representative of portions of this unit.

Slopes: Steep slopes with gradients between 10 and 60 percent are most common. Gradients of less than 10 percent are generally limited to colluvial slopes, swales, fans and alluvial bottom-lands.

Climate: Most of the unit is at elevations between 7,000 and 8,000 feet but there are extremes from 6,400 to 8,800 feet. Soil moisture conditions are more favorable for plant growth due to higher precipitation and lower evaporation associated with higher elevations. Data from the Marvine station show a mean annual precipitation of about 20 inches, a mean annual temperature of nearly 40° F., and a frost-free period of 47 days. Since unit 5 extends west to the State line, a range of from 15 to 20 inches in annual precipitation and 45 to 100 days in length of frost-free period can be expected.

Soil parent materials: Parent materials consist of mixed alluvium, colluvium, and outwash deposits along streams and valleys. Gravelly and stony valley fill is extensive along the lower mountain slopes. Parent rocks are chiefly sandstones, quartzites, shales and basalt. They have furnished the source for much reworked material in which soils have formed.

The approximate composition of the unit by Great Soil Groups is shown below. Estimates were not made for Regosols as they are included within the zonal soils:

Percent	1949 Great Soil Group	1965 Great Group, Subgroup or Family
45	Chernozem soils	Argiudolls and Argiborolls Hapludolls and Haploborolls
35	Chestnut soils	Argiustolls and Haplustolls
15	Lithosols	Haplustolls and Hapludolls (Lithic)
3	Alluvial soils	Haplustolls and Haplaquolls
2	Land types (Rock outcrop)	Land types (Rock outcrop)

Dominate soils of this unit have dark gray or dark grayish brown surface layers that are high in organic matter content. Surface layers are loamy with sandy textures being most common. On steep colluvial slopes coarse fragments from higher lying rock ledges and outcrops are usually scattered over the surface soil. Subsoils are more clayey and may be sandy clay loam to clay in texture. Many subsoils contain gravel, stone, and rock fragments. Lime is usually leached to depths of 40 to 60 inches.

Moderately deep and deep soils are intermingled within this unit. At depths between 20 and 40 inches there is usually sandstone, shale or basalt under moderately deep soils. Deep soils have formed in valley fill and may have dark colored buried soils within the upper four feet of the profile. Some dark surface soils are unusually thick and extend to depths of 20 to 30 inches.

Erosion is slight to moderate. Most evident is that in cultivated fields where runoff water has concentrated and resulted in rilling and gullying. Under native cover, erosion has been limited to washing along stock trails and minor gullying along drainageways.

Soil Mapping Unit 8: Shallow dark colored soils of mountain cliffs and ridges.

Landscape: This unit extends as a narrow band above Spring Creek across the west side of Cathedral Bluffs and southeast nearly to the Garfield County line. Large oil shale sequence sections in the Green River Formation are exposed along the west face of Cathedral Bluffs.

Conspicuous features of the landscape are light colored cliffs and escarpments. The white, light gray to very pale brown exposed shale, marl, sandstone and limestone beds extend along an irregular, jagged strip seldom more than a mile or two wide. Above the cliffs are sharp rolling windswept ridge crests which form a divide between the Douglas Creek and Piceance Creek drainage basins, while below are very steep talus slopes. Included in the landscape are highly dissected uplands forming headwaters of intermittent drains that flow west and north into Douglas Creek.

Slopes: Slopes are irregular and broken. They usually extend for only short distances before changing in aspect. Slope gradients on rolling ridge crests above the cliffs are 5 to 25 percent. Between and below vertical cliff faces slopes range from 25 to 75 percent

Climate: Most of unit 8 is at an elevation between 8,000 and 8,500 feet but extreme limits are 7,000 to 8,700. Mean annual precipitation is 16 to 20 inches. The frost-free period and mean annual temperature is similar to that of unit 7. A striking difference characterizing unit 8 is that much of the annual precipitation is lost by evaporation and runoff on bare exposures and wind-swept ridges. Consequently, a smaller portion of total precipitation is available for plant growth than within unit 7.

Soil parent materials: Soil parent materials have been mainly calcareous shales and fine grained sandstones. Marly deposits and limestone beds are also common. There has been much local reworking of materials from residual beds. Many of the colluvial slopes contain high proportions of gravel and stone.

Composition of unit 8 by Great Soil Groups is estimated below:

Percent	1949 Great Soil Group	1965 Great Group, Subgroup or Family
65	Lithosols	Lithic Haploborolls Lithic Haplustolls Lithic Haplorthents
25	Regosols	Haploborolls Haplustolls
10	Land Types (Rock outcrop)	Land Types (Rock outcrop)

Soils of this unit are predominantly shallow. Usually underlying shales or fine grained sandstones are at depths of 6 to 20 inches. Soil depth changes frequently within short distances. Deeper soils with underlying parent beds at depths of 20 to 40 inches occupy about 25 percent of the unit. Plant roots enter most of the residual beds and most shales can be readily penetrated with digging tools.

On west and south facing slopes surface soils are lighter colored and limy. Shaly loams and gravelly sandy loams are the common surface soil textures on steep upper slopes. Deep soils containing high proportions of shale and stone occupy some lower colluvial slopes.

Erosion within this unit is mainly geologoc in character. Parent rocks, steep slopes and strong winds slow the rate of soil formation. In addition, much weathered material moves down slope as colluvium. Accelerated erosion is principally by wind on ridge crests where overgrazing had denuded shallow loamy soils. Gullying is limited to narrow drainageways occupied by deep, friable soils.

8. Vegetation

Vegetation in the area is predominantly of three major types: sagebrush, mountain shrub, and pinon-juniper. Other vegetation in lesser quantities including greasewood, saltbush, conifers, broadleaf trees, and grass.

The sagebrush and mountain shrub types together cover about 60% of the area. Sagebrush is located on the ridges, slopes and in the drainage bottoms at higher elevations and in "parks" within the pinon-juniper type. The mountain shrub type may include oakbrush, serviceberry, or mountain mahogany, with an understory of grass. Drainage bottoms at lower elevations are characterized by greasewood. The saltbush type is also found at the lower elevations.

The pinon-juniper type covers about 36% of the are. As elevation increases, the percentage of pinon decreases and juniper and mountain browse increase. The broadleaf trees and conifers are located at the higher elevations, primarily on northfacing slopes. There is no commercially valuable timber in the area although the juniper is cut for posts and poles by ranchers.

A limited acreage of privately-owned valley lands, (about 5% of the area) are cultivated, producing mostly hay crops.

No large amounts of poisonous or noxious plants are known in the area.

The following table reflects the grass and browse species of major importance within the area.

Grass species of major importance:

Genus	Species	Common Name
Agrophyron	smithii	Western Wheatgrass
Agropyron	dasystachyum	Thick Spike Wheatgrass
Agropyron	spicatum	Bluebunch Wheatgrass
Oryzopsis	hymenoides	Indian Rice Grass
Poa	secunda	Sandburg Bluegrass
Bromus spp.		Bromegrass

Browse species of major importance are:

Genus	Species	Common Name
Artemesia	tridentata	Big Sagebrush
Artemesia	nova	Black Sagebrush
Purshia	tridentata	Bitterbrush
Cercocorpus	montanus	Mountain Mahogany
Atriplex	confertifolia	Shadscale
Atriplex	canescens	Fourwing Saltbush
Amelanchier	alnifolia	Serviceberry

In recent years large upland areas in the Piceance Basin have been cleared of pinon-juniper and sagebrush by dragging a heavy chain between large tractors. Native and special grass seed is planted in the chained areas with the objective of increasing forage yield for stock and wildlife. Pipeline rights of way have been planted in grass generally with good crop yield, on un-matured dirt fill.

Reportedly the grass yield of areas which have been denuded of juniper-pinon sage is several times more than the unchained land. The occasional forest or brush fire in the area commonly is followed by improved grass stands and improved stock grazing conditions. The availability of sufficient ground moisture in this semi-arid region is the most important factor in development of forage grass.

9. Recreation

The hunting of mule deer during October/November is the major annual recreation use of the Basin. Game, Fish and Parks Division records show that over 5,000 hunters visit the area each year during the hunting season and harvest an average of 5,500 deer. A few elk and black bears are also taken each year.

Non-residents constitute a large proportion of the Piceance Creek hunters. Many utilize trailers or campers brought from their home states. Local ranchers commonly guide out-of-state hunters from their ranch headquarters for a fee.

The Piceance Creek basin is sparsely populated, but is generally accessible to motor vehicles. The area is visited sparingly by tourists at times other than during the big game hunting season. This is probably because of the proximity of the area to more desirable country with high recreation values.

Fishing in the basin is limited to several man-made ponds in the major drainage bottoms and in the headwaters of several small live streams.

There are no commercial recreation facilities within the basin other than ranch headquarters. Recreational access to some public land is impaired as a result of private ownership of adjacent lands. Service centers utilized by hunters and local recreationists are the towns of Rifle, Meeker, and Rangely; each about 20 miles from the basin perimeter. These communities also serve fishermen, hunters, winter sports participants and campers utilizing the high quality recreation facilities of the White River National Forest and surrounding area.

In the environs around but somewhat distant from the Piceance Creek basin there are many other recreational activities and opportunities. Some of the more spectacular scenic areas in the region surrounding the oil shale lands include Dinosaur, Colorado, Arches, Canyonlands and Black Canyon National Monuments. Numerous scenic areas and campgrounds of the National Forest, such as the White River and Uncompahgne National Forest. These prime scenic areas are within 100 miles of the oil shale lands. Some of the country's better ski areas are located near Snowmass, Aspen and Vail, Colorado, less than 100 miles from the oil shale areas. Municipal or club golf courses, swimming pools and rodeo grounds are available to the public in most of the larger towns near the oil shale lands.

The quality and type of outdoor recreation, like most uses of the land are primarily controlled by the landscape and its attending components of soil, climate, relief, water, vegetation and wildlife. In the Piceance Creek Basin the primary outdoor recreation activities are oriented around hunting, fishing, and camping, The 800,000 odd acres of the basin are located mostly in the central third of Rio Blanco County, with a small portion lapping over into Garfield County. Rio Blanco and Garfield Counties along with Moffat County to the north make up the Northwest Colorado Recreation Region (R6). 1/ All three counties contribute a significant portion to the hunting, fishing, and camping resources of Colorado.

Recreation inventories (2,3) for Rio Blanco County reveal that outside of the Piceance Creek Oil shale area there are approximately 25 private ranches that cater to hunting and fishing clientele; and 16 resort operators who specialize in providing hunting, fishing and rural living accommodations. In addition to these accommodations there are 78 ranches in the county, most all outside of the shale area, which provide hunting on a fee basis; average size of ranches is 5,00 acres with 20 hunters per ranch. Hunting outfitters in the county total 27.

1/ 1970--Colorado Comprehensive Outdoor Recreation Plan.
2/ 1965--Bureau of Outdoor Recreation Survey of Public Areas and Facilities, USDI.
3/ 1971--An Appraisal of Outdoor Recreation in Rio Blanco County, Colorado, USDA, SCS.

Public recreation in Rio Blanco County is located mostly on National Forest lands in the eastern third of the county and on Bureau of Land Management lands in the western half of the county. Major recreation areas, called recreation complexes, administered by the BLM within or around the perimeter of the Piceance Creek Basin include: (Douglas Creek (400,000 acres), Piceance (268,476 acres), Strawberry (40,000 acres), and Yellow Creek (343,468). Visitation to these areas in 1965 totaled approximately 30,000 visitor days.

The potential for the recreation development such as: camping, pack trips, cold water fishing, big and small game hunting, and vacation ranches is high for Rio Blanco County; low for warm water fishing; and medium for water sport areas, and waterfowl hunting.

Rio Blanco County includes important natural, scenic or historic areas. Approximately twenty areas have been inventoried and cited: [3/] the most notable include the Flat Tops Wilderness Area, Douglas Creek and Missouri-Texas Creeks, Moon Canyon, Cathedral Bluffs, Raven Ridge and Piceance Creek. White River Road-

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3/ 1971--An Appraisal of Outdoor Recreation in Rio Blanco County, Colorado, USDA, SCS.

U. S. Highway 40, which traverses east to west just north of Piceance Creek Basin, is being considered as a potential scenic highway.

Piceance Creek Basin is noted for providing a significant portion of the habitat for the largest migratory herd of mule deer in the United States. The Basin also provides limited habitat for elk. The hunting of mule deer during a fall hunting season is a major use of the Basin annually. During 1960-69 period sportsmen took an average of 6,000 deer annually from within the Basin thus ac accounting for approximately 10 percent of the total State deer harvest and 40,000 recreation days.

As is the case for most of the recreationists of the Northwest Colorado Recreation Region (R6) non-residents comprise a large portion of the Piceance Creek hunters. Of the 40.8 thousand who hunted for mule deer in the Basin in 1969, 29.4 thousand were non-residents. Most visitors to the Basin utilize campers brought from their home States. Developed facilities for recreational activities in the Basin are generally lacking.

10. Archaeological and Historical Values

There are no historic sites listed for Rio Blanco County, Colorado, in The National Register of Historic Places.

Rio Blanco County has identified the Ryan Gulch school as a local historic site.

There are indications in the Piceance Basin that campsites of presently unknown nomadic hunting peoples, possibly Ute and older, may be found on the ridges above the valleys, in select caves and near water sources.

Farming activity along the main drainages precludes any surface indications of Indian activity. Gully erosion of some bottom land may expose evidence of early peoples.

Archaeological study of the oil shale areas has been very limited. The Midwest Archaeological Center, National Park Service, Lincoln, Nebraska; Colorado Historical Society, Denver, Colorado; and Department of Anthropology, Colorado University, Boulder, Colorado; have no record of known archaeological sites occuring on or near the public oil shale areas being considered for development.

11. Socio-Economic Resources

The Piceance Creek Basin is located on the "western slope" of Colorado, at some distance from any major population center. Access routes include U. S. Highway 6 along the Colorado River, Colorado Highway 64 along the White River, and Colorado Highway 13 on the east and 139 on the west. (Figure II-27). Many unsurfaced roads and rought trails lead into and across the area from the main access routes. A paved county road traverses the area along Piceance Creek. The shale area, approximately 1200 square miles, is sparesely settled, with 150 people living in the Basin itself. The inhabitants are generally widely dispersed and are engaged in the livestock, mineral, oil and gas industries, or in farming.

The principal oil shale areas of the Piceance Creek Basin are in Garfield and Rio Blanco Counties. Mesa County also contains a minor amount of oil shale.

A description of the principal supply centers and facilities of the communities in the surrounding area is as follows:

Grand Junction the County Seat of Mesa County and the largest community of Western Colorado, is a transportation hub with rail, truck and highway communication with Western Colorado and more distant points, and with frequent jet air service principally to Denver and Salt Lake City. Grand Junction is also a commercial and medical center for the region, with a number of wholesale supply firms and services, as well as medical, educational and other professional services.

The Town of Rifle, situated in Garfield County on the Colorado River at the southwestern corner of the Piceance Creek Basin, has been oriented towards both industrial activity while acting as an agricultural supply center. It is the site of a Union Carbide vanadium-uranium mill which is now being closed and is the nearest community to the Bureau of Mines' research facility at Anvil Points. The Denver and Rio Grande Railroad has made it a shipping point for livestock from the Piceance Creek Basin.

Glenwood Springs, the County Seat of Garfield County, is situated at the junction of the Roaring Fork and Colorado Rivers. This community has become the focal point of distribution of goods and services to the very large areas drained by the Colorado, Eagle, Roaring Fork, Frying Pan and Crystal Rivers.

The Town of Meeker, the County Seat of Rio Blanco County, is situated on the White River northeast of the oil shale area. It is mainly an agricultural supply center. The town population is about 1500.

The Town of Rangely, in Rio Blanco County, is situated on the White River, northwest of the Piceance Creek Basin, It is an operation center for the Rangely oil field, and the site of a western Colorado junior college. The town population is also about 1500.

The present economic and social status of Garfield, Mesa, and Rio Blanco counties are briefly summarized below.

In 1970, Garfield County had a population of 15,000. The total number of employed persons during that same year was 6,000 while the unemployment rate was 4.9%. Retail trade provided the greatest amount of income to the community in 1963, with sales totaling over $20 million. The agricultural sector, which is considered one of the primary sources of income for the area, provided employment for 483 persons in 1970. The value of the farm products sold in 1964 (including livestock) was $5 million. Total revenue to the county government in Garfield County in 1962 was $4 million and total expenditures were $5 million. In 1962 the county expended $2 million for educational purposes.

Mesa County, located south of the Piceance Basin, has the largest population of the three counties. In 1970, the population of Mesa County was 54,400. Grand Junction, located in Mesa County, had a population of 20,100. Slightly less than one-half of Grand Junction's employed persons are either blue collar or service workers. The ratio of blue collar workers to the total work force is the in the county as it is in Grand Junction. Approximately one-third of the county's total number of employed persons are located in Grand Junction.

Mesa County government revenue received was $14 million in 1962. Expenditures during that year were close to $16 million, of which $8 million were spent on the local school systems. The major source of income to the community was from retail trade in 1963 (sales totaled $72 million). Commercial income from the agricultural sector (valued at $12 million) was only 1/6 as large as retail trade. The total acreage farmed in Mesa County, however, exceeds that of the other two counties.

Rio Blanco County will be most directly affected by the oil shale development because of its location which includes a major portion of the Piceance Basin. In 1970, the total county population was 5,000. Meeker, the county seat, and Rangely are principal towns of the county.

Rio Blanco County has the highest per capita property tax receipts ($325 as compared to $133 for Mesa County and $157 for Garfield County) of the three counties. However, the amount of revenue collected in 1962 was the least of the three. In 1962, Rio Blanco County government revenue was $3.0 million, less than one-quarter of the revenue collected by the Mesa County government. Rio

Blanco County expended $.9 million in 1962 for educational purposes, which was more than one-quarter of their total annual revenues. The towns of Rangely and Meeker are considered to have excellent school systems. Each community has a hospital with at least 20 beds and in 1962, $.4 million were expended by the county for health and hospital services. The county had 12 resident physicians, dentists and/or medical practitioners in 1970.

The value of the farm products sold in Rio Blanco county in 1964 ($4.0 million) was two-thirds as large as the total sales from retail trade ($6.0 million). The county had an unemployment rate of 2.1% in 1970, which was below both the national average and the rate for the other two counties. The total number of employed persons in 1970 was 2,000 of which 40% were employed in white collar occupations, 45% in blue collar and service related industries and 15% in the agricultural sector.

Total employment in the minerals sector in the three counties was 1,143 in 1970 (Garfield County 395 persons, Mesa County 468, and Rio Blanco County 280). The value of production in Garfield County was $3.4 million, consisting mainly of vanaduim, uranuim and sand and gravel. Rio Blanco County's mineral production was almost totally petroleum and natural gas and was valued at $41.3 million in 1970.

Table II-9 -- County and City Social Characteristics, 1970 -- Colorado 1/

	Population (1,000)	No. of Households (1,000)	School Enrollment Primary (1,000)	School Enrollment High School (1,000)	Median School yrs. completed (25 yrs. & over)
Garfield County	14.8	5.0	2.7	1.2	12.2
Mesa County	54.4	17.6	9.5	4.1	12.3
Rio Blanco County	4.8	1.5	.9	.5	12.4
Total	74.0	24.1	13.1	5.8	12.3
City of Grand Junction (Mesa Co.)	20.1	7.2	3.0	1.3	12.3

1/ Source: 1970 Census of Population, General Social and Economic Characteristics--Colorado. U.S. Department of Commerce, Washington, D.C., 1972

Table II-10. County and City Economic Characteristics, 1970 -- Colorado 1/

	Employment					
	Total Employed 16 yrs. & over (1,000)	White Collar & Service (1,000)	Blue Collar & Service (1,000)	Agricultural (1,000)	Percent Unemployed	Median Family Income
Garfield County	5.9	2.5	2.9	.5	4.9%	$8,380
Mesa County	20.1	9.9	8.9	1.3	5.4%	8,065
Rio Blanco County	2.0	.8	.9	.3	2.1%	8,010
Total	28.0	13.2	12.7	2.1	5.3%	$8,122
City of Grand Junction (Mesa Co.)	7.7	4.2	3.4	.1	6.1%	8,092

1/ Source: 1970 Census of Population, General Social and Economic Characteristics--Colorado. U. S. Department of Commerce, Washington, D.C., 1972.

Table II-11 .-- County Economic Indicators, Government -- Colorado[1]

	Local Government Finances[2]						
	Revenue		Expenditures				
County	Total Mill $	Property Tax Per Capita $	Total Mill $	Education Mill $	Highway Mill $	Health and Hospital Mill $	Other Mill $
Garfield	4.0	157	5.0	2.0	.6	.5	1.9
Mesa	14.0	133	16.0	8.0	2.0	.1	5.9
Rio Blanco	3.0	325	3.0	.9	.6	.4	1.1
Total	21.0	150	24.0	10.9	3.2	1.0	8.9

1 - Source: County and City Data Book, 1967, U.S. Bureau of Census, Washington, D.C., 1967
2 - 1962

Table II-12 -- County Economic Indicators, Private -- Colorado[1]

County	Retail Trade[2]		Services[2]		Agriculture[3]		
	Total Establishments	All Sales Mill $	Total Establishments	All Receipts Mill $	Acreage Farmed (1,000)	Total Commercial Farms	Value of Farm Products Sold Mill $
Garfield	187	21.0	131	3.0	556	351	5.0
Mesa	475	72.0	367	9.0	716	917	12.0
Rio Blanco	67	6.0	65	1.0	613	170	4.0
Total	729	99.0	563	13.0	1885	1438	21.0

1 - Source: County and City Data Book, 1967, U.S. Bureau of Census, Washington, D.C., 1967

2 - 1963
3 - 1964, preliminary

12. Land Use

Public lands in the Piceance Creek Basin serve primarily as livestock forage areas, wildlife habitat, limited natural gas and natural gas liquids production, as a watershed, and for outdoor recreation. These uses have not changed appreciably in recent years. The public domain lands are all included in two Grazing Districts administered under the Taylor Grazing Act. About 60,000 authorized animal unit months of forage use are distributed among 45 permittees.

Gas wells, pipelines and a gas liquids plant of the Piceance dome are on public lands of the Piceance Creek Basin.

Numerous other oil and gas test wells in the Basin are shut in. Some marginal gas wells are being considered for future commercial development if they can be stimulated by fracture techniques.

The privately-owned lands are used mostly for farming and livestock grazing. A number of hunting camp-buildings on private land are used during deer hunting season.

13. Land Status

Total land area in the two Bureau of Land Management (BLM) planning units of major significance is 805,420 acres. Land ownership in the two units is as follows:

BLM Planning Unit	% Federal	Public Land Acres	State Acres	Private Acres
Piceance Basin	61%	264,580	11,526	97,780
Yellow Creek	79%	343,989	18,823	68,719

C. Utah (Uinta Basin)

1. Physiography

The Uinta Basin, a broad structural and physiographic basin, is a depression bounded on the east by the cliffs west of the Douglas Creek Arch, the Uintah Mountains on the north, the Wasatch Mountains on the west, and the Roan Cliffs on the south. The richest and thickest deposits of oil shale lie mostly in the Uintah County portion of the basin, which is thus the area of primary concern.

The topography consists of rough mountain terrain and flat valleys, sharply dissected by deep gulleys with adjoining rock capped ridges. Oil shale crops out in cliffs and ledges on the south and east sides of the Basin. Elevations vary from 4,600 to more than 8,000 feet. An aerial view of a typical oil shale exposure is shown in Figure II-30. The area drains into the White and Green River systems and eventually into the Colorado River.

The Green River is the main flowing body of water in the area cutting through the best oil shale deposits in a northeast to southwest direction. The other source of water is the westward-flowing White River, which empties into the Green within the bounds of the Uinta-Ouray Indian Reservation. The Duchesne and Uinta River enter the Green River from the west.

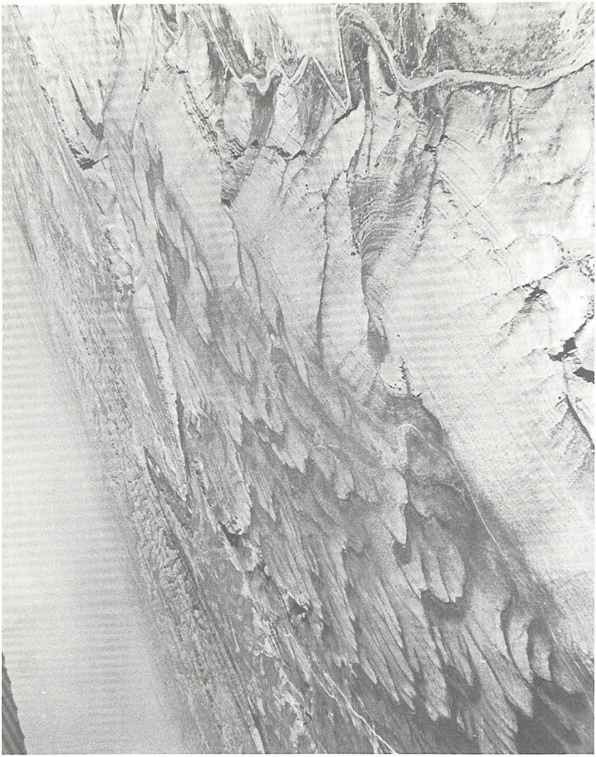


Figure II - 30 Aerial view of Green River Formation escarpment in west wall of Hells Hole Canyon, Utah

2. Climate

This area is semi-arid, characterized by low relative humidity and a wide range of daily temperatures. Summer daytime temperatures reach the 80's and 90's, while nights drop to the low 50's. Winters are cold, with day temperatures ranging from 20 degrees Fahrenheit to 28 degrees Fahrenheit during January. Mean annual temperature is 45 degrees Fahrenheit.

Growing seasons vary greatly, with records showing frost-free periods of 90 days to 218 days annually. The average growing season is about four months, from late May to late September.

Preceipitation averages about 7 inches at the lower elevations and 15 inches at the higher levels. Records show that about 55% of the precipitation falls as rain during the growing season and the remaining 45% falls as winter snow. Most rainfall comes from thunderstorms, which are short-lived, but of high intensity. As a result, most of the moisture is lost through rapid runoff and evaporation. Snowfall is light, averaging 30" annually. However, snow melt in the spring is slow, allowing the soil to absorb most of the snow moisture.

Winds are irregular and light, except when associated with local thunderstorms. Although there is little wind erosion, winds affect the vegetation of the area by evaporating moisture from the soils before it becomes available for plant use.

3. Geology

The Uinta Basin is a sedimentary, structural, and topographic basin.

Oil shale of the Green River Formation is exposed along the south and east margins of the basin, and is concealed by younger sediments in the central and northern parts of the basin. From available drilling information, the thicker, richer oil shale is in the eastern half of the basin, mostly concealed by younger rocks of the Uinta Formation. Geologic maps and description of the oil shale in the southeastern part of the Uinta Basin are shown by Cashion (1967) U.S.G.S. Professional Paper 548. The reader is referred to his report for details of distribution of the rock units, oil shale, gilsonite, bituminous rock and petroleum in the Green River Formation of the area.

a. Stratigraphy

Surface rocks within the area presently considered for development are, for the most part, beds of the Uinta Formation that are composed of brown and gray sandstone, siltstone, and shale. The Green River Formation is exposed in a relatively small part of the total area of the tracts.

The upper part of the Green River Formation is composed chiefly of light-gray to dark-gray beds of marlstone, low-grade oil shale, and some tuff. Saline minerals are found in these upper layers in the form of very thin lenses or beds and small pods. Underlying the upper sequence is a series of dark-gray oil-shale beds that occur in the formation adjacent to the Mahogany zone and can be considered as a middle sequence of the Green River Formation. That part of the formation below the Mahogany zone is composed principally of interbedded brown and gray sandstone in the southeastern part of the Uinta Basin.

The stratigraphic relationships of the oil shale and associated rocks of the basin are shown in Figure II-31.

b. Geologic Structures

The Uinta Basin is a broad asymetric synclinal basin. Along the southern flank of the basin the oil shale beds dip gently northward 100 to 200 feet per mile. The trough or axis extends east-west near the north margin of the basin, and the north flank of the basin is steeply titled toward the axis.

A northwest trending series of graben faults offset the oil shale and related rock in several parts of the Uinta Basin. The displacements are generally presumed to be small.

4. Mineral Resources

a. Oil Shale

The lower grade oil shale in the Uinta Basin as known from exploration underlies about 2,500 square miles of the Basin (Cashion, 1967, U.S.G.S. Prof. Paper 548, p. 31) and contains 320 billion barrels

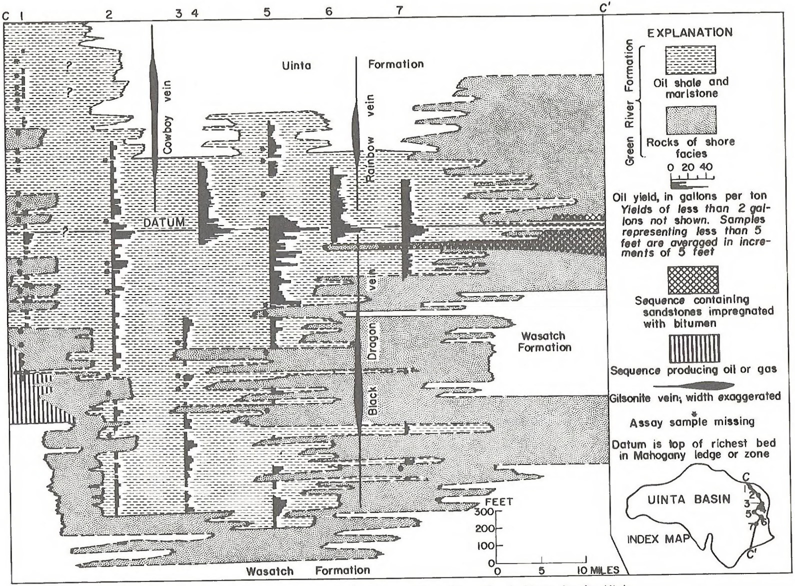


Figure II - 31 Cross section C-C' of Green River Formation in Uinta Basin, Utah of oil equivalent. The higher grade shale of the Basin contains approximately 80 billion barrels in a 1,000 square mile are of the eastern part of the basin, where thicknesses of 15 feet or more of rich (30 gallon per ton) shale are reported.

b. Oil and natural gas

Several large oil fields have been developed in the Wasatch and Green River Formations in the central and northern parts of the Uinta Basin. (Figure II-6). The oil fields are situated north of the richer oil shale areas.

Several gas fields have been developed in reservoirs below the oil shale bearing rocks within the rich oil shale areas. The reserves in selected reservoirs are not reported by the producing companies. The Uinta Basin has been only partly explored for oil and gas. Exploration has tested only the upper part of the total sedimentary rock sequence. The sediments below the presently explored deposits may contain undiscovered oil and gas accumulations.

c. Tar Sands

Tar sand deposits (rock asphalt of Figure II-8) are described in the Green River and Wasatch Formations of the Uinta Basin. Two of the principal deposits, at Sunnyside and near Vernal, Utah lie marginal to the area of oil shale interest. A third deposit known as P.R. Springs deposit is in the sandstone beds of the Green River Formation, situated 20 to 100 feet below the rich oil shale of the Mahogany ledge in the southeastern outcrop areas of the Uninta Basin. The tar sands are estimated to contain about 7 billion barrels of bitumen.

d. Gilsonite

Gilsonite and similar solid hydrocarbon veins are numerous in the richer oil shale areas. The gilsonite veins are generally in rocks. above the oil shale. They contain about 36-40 millions tons of hydrocarbon. They have been mined for many years. The wider veins are partly mined out.

e. Other minerals

Nahcolite (NaHCO3) occurs as very thin lenses or beds and small pods in the upper part of the Green River Formation, mostly in an interval extending from 300 to 600 feet above the Mahogany zone. The quality is probably not great enough to allow profitable recovery.

There are minor occurrences of uranium in the lower part of the Uninta Formation and the upper part of the Green River Formation of the eastern Uninta Basin. None has been noted in the tracts.

5. Water Resources

a. Surface Water

Streams in the Unita Basin which are within the area of the oild shale deposits drain relatively low elevation watersheds which receive small amounts of precipitation each year, therefore, local streamflow is very limited in amount. Up to 250,000 acre-feet of water annually could be made available from the Green, White and Yampa Rivers for development of oil shale in the Uinta Basin. This could be made available from the existing Flaming Gorge Reservoir on the Green River and potential reservoir sites on the White and Yampa Rivers. The Utah Division of Water Resources holds a pending application to appropriate 350 cubic feet per second, plus 250,000 acre-feet of water from White River, its tributaries and ground water. Utilization of water from the White and Yampa River would require construction of dams and reservoirs. Additional water in the area could be made available by purchasing and changing the nature of use and paint of diversion of existing senior water rights.

Streamflow records for the White River near Watson, Utah show a 47-year mean discharge of 702 cubic feet per second. Dissolved solids concentration (20 years of record) ranged from 209 to 2,380 mg/1; and the discharge-weighted mean for 1969 was 408 mg/1.

Records for the streamflow station on the Green River near Jensen, Utah, show a mean flow of 4,307 cubic feet per second. The disolved solids concentration was 391 mg/1 in 1969.

The stream low at the gaging station on the Colorado River near Cisco, Utah, has a mean discharge (59 years) of 7,711 cubic feet per second. Dissolved solids concentrations ranged (in 42 years) between 202 and 2,670 mg/1. The mean concentration in 1969 was 631 mg/1.

b. Ground Water

The Green River Formation in Utah reportedly yields from less than 1 to 200 gpm of water to wells. In Sec. 36, T.9N.,R.20E., test pumping a well that penetrated three water-bearing zones in the Formation indicated very low transmissivities (6 to 18 gallons per day per foot). The potentiometric head was sufficient to cause the test hole to flow 5 gpm at the land surface. Dissolved-solids content of water from the well ranged from 37,000 to 72,700 mg/1. However, ground-water quality in the Basin can be expected to range from fresh to briny. The Green River Formation contains probably more water in storage than any other formation in the Uinta Basin, but much less than in the Piceance Creek Basin of Colorado.

The Uinta Formation yields water that ranges in quality from fresh to briny. Few data are available on well yields. An oil well in T.4.S., R.5W. reportedly yielded 30 gpm. A water well in T.3S.,R. 3W. yielded 20 gpm (Feltis, 1966).

Sandstone beds in the Duchesne River Formation yielded 2 to 10 gpm of fresh water to municipal wells owned by the city of Roosevelt (Feltis, 1966). No other ground water data are available.

6. Wildlife and Fish

Utah's Uninta Basin area provides 1,335,000 acres of important mule deer winter range, of which 250,000 acres are considered critical as winter feeding areas. An average annual harvest of 8,000 mule deer has been recorded in this area. Bears have been reported in the area but are scarce. Transplanted antelope have become established and are increasing in numbers. Additional transplants into the area are planned by the Utah Fish and Game Division. Small numbers of elk are present in restricted areas. Mountain lions exist in the area, but no data exists to reflect the population status. Bueau of Land Management estimates indicate that a herd of about 130 wild horses inhabit the Utah oil shale lands.

Bear, coyotes, porcupine, and a variety of native and introduced game birds also thrive in this area. The cottontail is the most important small game species with an annual harvest varying from 10,000 to 15,000. Sage grouse occur in limited numbers with restricted distribution. The Chukar partridge has been introduced to the area and the population is increasing. Over 1,000 Chukars are harvested annually, and more transplants are anticipated. Use of oil shale area by waterfowl, muskrat, mink, and beaver occurs primarily on the White-Green River channels and adjacent tributaries.

a. Fish

Headwater areas provide some trout fishing, although heavy siltation and poor water quality has created a generally degraded fish environment. Three rare fish species, the Squawfish, Humpback Sucker, and Bluehead Sucker, inhabit the Green River.

7. Soils

Soils of the Unita Basin vary from none in the cliff and steep slopes of the canyon areas to deep alluvial soils along some areas of the larger streams and plains country. (See Figure II-32)

The surfaces in this area are highly erodible and contribute a high silt load to the Colorado River system. Soil erosion conditions on the three units (Bonanza, Rainbow, and Book Cliffs) containing 875,000 acres of public lands are:

Erosion Classifications

	Slight	Moderate	Critical	Severe
Bonanza (337,000 acres)	--	9%	64%	27%
Rainbow (299,000 acres)	1%	45%	54%	--
Book Cliffs (240,000 acres)	15%	77%	8%	--

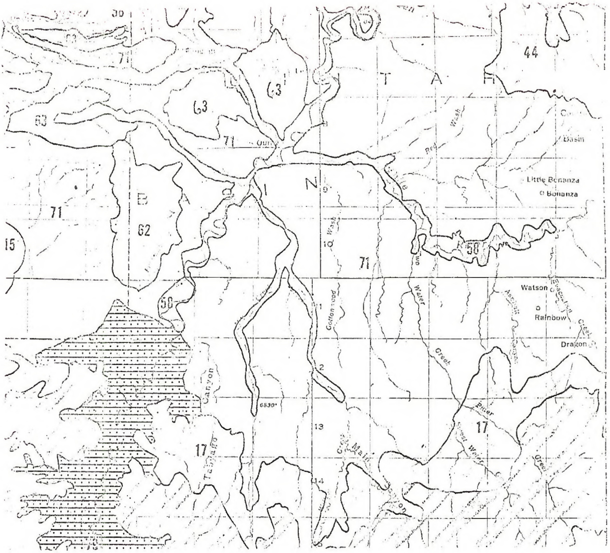


Figure II-32.-- SOIL ASSOCIATION MAP
STATE OF UTAH

Scale; 1 inch equals approximately 8 miles
Prepared by Soil Conservation Service

Technical discussion of the soils of the better oil shale area is the Uinta Basin follows:

Composition of map unit 71 (Fig. II-30) by Great Soil Groups (1949); Great Groups, Subgroup, or Family (1965) and land types is estimated as follows:

Percent	1949 Great Soil Group	1965 Great Group, Subgroup or Family
50	Red Desert	Typic Torriorthents
25	Rendzinas	Lithic Calciorthids
	Lithosols	
	(Solonetz)	(with inclusions of Lithic Natrargids and Badlands)

Typic Torriorthents are shallow soils over weathered soft marine shales. They have thin light yellowish brown calcareous fine loamy or fine silty surface horizons and fine silty or clay subsoils. The soft shale bedrock usually is at depths of less than 20 inches. Relief is undulating to rolling.

Chipeta and Persayo Soil Series are representative of this subgroup.

Lithic Calciorthids are shallow over sandstone or interbedded sandstone or shale bedrock. The soils are light colored; calcareous sand or coarse loamy surface horizons; underlain by a loam or stony loam accumulation zone.

No Soil Series has been established for this subgroup.

All of these soils are well drained; permeability is slow; runoff is rapid and sediment production is high especially from intense summer storms.

Native vegetation is shadscale, greasewood, saltbush, galleta grass and Indian ricegrass.

These soils are in Hydrologic Group D.

Composition of map unit 58 by Great Soil Groups (1949); Great Group, Subgroup or Family (1965); is estimated as follows:

Percent	1949 Great Soil Group	1965 Great Group, Subgroup or Family
25	Alluvial	Aquic Xerofluvents
30	Alluvial	Aquic Ustifluvents
20	Alluvial	Typic Torrifluvents (with inclusion of Typic Natrargids and Vertic Fluvaquents)
	(Solonetz)	

This association occurs along recent flood plains and low terraces adjacent to major rivers (White River). Relief is smooth to gently undulating.

The Aquic Xerofluvents are deep soils that have gray, calcareous loamy or silty surface horizons underlain by stratified subsoil that ranges in texture from coarse loamy or course silty to fine sandy loamy or fine silty. Mottling is common below 10 inches. The Abraham Soil series is representative of this subgroup.

The Aquic Ustifluvents are deep soils with brown to pale brown, moderately calcareous, loamy surface horizon. Underlain by stratified coarse loamy to fine loamy subsoils. They are mottled below depths of 20 inches. Water table ranges between 20 to 40 inches. The Green River Soil Series is representative of the subgroup.

Typic Torrifluvents are deep soils with light colored calcareous loamy or silty surface, coarse silty, fine loamy or fine silty subsoils. The Ravola Soil Series is typical of this subgroup.

Permeability is moderate for all of these soils except for the Natragids which have slow permability. Runoff is medium to rapid and sediment production is high because of stream cutting during periods of high stream flow.

Native vegetation is cottonwood trees, willows, salt cedar, greasewood and associated grasses and forbs.

These soils are in Hydrologic Group B and D.

8. Plant Life

There are four major vegetative types within the area. Because of the gradual changes in both elevation and soils the vegetative types gradually change forming larger transition zones than are found in most areas.

a. Pinon-juniper Type

This type is mostly juniper with a few pinon only in the higher more favorable spots. The pinon-juniper type covers about 10% of the area.

The highest value is water shed and winter deer range, but there is some livestock grazing.

b. Sagebrush Grass Type

This type covers about 10% of the lands. It lies just below or in open parks within the pinon-juniper type. It is on the most fertile, and deepest soils (two to several feet deep).

There is a gradual transition from this type to the desert shrub type. In this transition area the sagebrush is mostly black sage (Artemisia nova), and the soils are shallower and rockier. This transition area is mostly located on the south slopes, and in lower, dryer sites.

c. Desert Shrub

This type covers about 60% of the area. The vegetative composition and soil type vary greatly. About half of this type is very similar to the black sage transition area above, but contains more salt bush (Atriplex spp.) and other low shrubs. Some of the desert shrub type is on very sandy soils and includes very few plants other than horse brush (Tetradymia Spp.) and rabbit brush (Chrysothamnus Spp.). About one third of this type has a good cover of salt bush, other low shrubs and grass. As the clay and salt content in the soil increases the portion of grass and total density decreases and the salt bush increases.

d. <u>Salt Desert Shrub</u>

This type covers about 15%. The soils and vegetation of this type are similar to the salt bush areas of the desert shrub type, but has more salt bush as a result of more clay and salt in the soil.

Some areas of the salt desert shrub are on bare shale with almost no soil development, with very sparse stand of mat salt bush (Atriplex corrugata), nuttall salt bush (Atriplex nuttallii) and yellow brush (Chrysothamnus Spp.). This bare shale is mostly in a severe erosion hazard condition, and contributes considerable silt into the Green River.

There are three minor vegetative types within the unit. These are:

(1) Cottonwood--along the bottoms of the Green and White Rivers.

(2) Barren--This is similar to the bare shale portion of the salt desert shrub, but has too little vegetation to call a vegetative type.

(3) Greasewood--weeds. This is found along most of the major drainage bottoms.

(4) Waste--These are lands which are too rough, steep, and rocky to support significant vegetation.

The dominant plant species for each of the four major vegetative types, in order of importance, are as follows:

	Common Name	Scientific Name
Pinon-Juniper Type	Grasses	
	Bluestem wheatgrass	Agropyron smithii
	Wheatgrass	Agropyron spp.
	Curly grass	Hilaria jamesii
	Indian Rice grass	Oryzopsis hymenoides
	Needle & Thread grass	Stipa comata
	Forbs	
	Russian thistle	Salsola kali
	Stickseed	Lappula spp.
	Buckwheat	Eriogonum spp.
	Lupine	Lupinus spp.
	Loco weed	Astragalus spp.
	Shrubs	
	Black sage brush	Artemisia nova
	Big sage	Artemisia tridentata
	Snake weed	Gutierrezia sarothrae
	Low Yellow brush	Chrysothamnus viscidiflorus
Sagebrush Type	Grasses	
	Curly grass	Hilaria jamesii
	Indian Rice grass	Oryzopsis hymenoides
	Bluestem wheatgrass	Agropyron smithii
	Wheatgrass	Agropyron spp.
	Forbs	
	Russian thistle	Salsola kali
	Stickseed	Lappula spp.
	Mustard	Lepidium spp.

	Common Name	Scientific Name
	Shrubs	
Sagebrush Type (Continued)	Big sage	Artemisia tridentata
	Black sage	Artemisia nova
	Shadscale	Artiplex confertifolia
	Snakeweed	Gutierrezia sarothrae
	Low yellow brush	Chrysothamnus viscidiflorus
Desert Shrub Type	Grasses	
	Curly grass	Hilaria jamesii
	Indian Rice grass	Orysopsis hymenoides
	Needle & Thread grass	Stipa comata
	Cheat grass	Bromus techtorum
	Forbs	
	Russian thistle	Salsola kali
	Halogeton	Halogeton glomeratus
	Cactus	Opuntia spp.
	Desert mallow	Sphaeralcea spp.
	Shrubs	
	Black sage	Artemisia nova
	Shadscale	Artiplex confertifolia
	Low yellow brush	Chrysothmanus viscidiflorus
	Big Sage	Artemisia tridentata
	Horse brush	Tetradymia spp.
	Greasewood	Sarcobatus vermiculatus
	Nuttall saltbush	Atriplex nuttallii
	Snake weed	Gutierrezia sarothrae
	White sage (winterfat)	Eurotia lanata
	Spiny hopsage	Grayia spinosa
Salt Desert Shrub Type	Grasses	
	Curly grass	Hilaria jamesii
	Indian Rice grass	Oryzopsis hymenoides
	Squirreltail	Sitanion hystrix
	Cheat grass	Bromus tectorum
	Six week fescue	Festuca octiflora

	Common Name	Scientific Name
Salt Desert Shrub Type (Continue)	Forbs	
	Indian wheat	Plantago spp.
	Russian thistle	Salsola kali
	Stick seed	Lappula spp.
	Halogeton	Halogeton glomeratus
	Cactus	Opuntia spp.
	Desert mallow	Sphaeralcea spp.
	Buckwheat	Eriogonum spp.
	Shrubs	
	Nuttall saltbush	Atriplex nuttalli
	Shadscale	Atriplex confertifolia
	Black sage	Artemisia nova
	Shortspine horsebush	Tetradymia spinosa
	Big sage	Artemisia tridentata
	White sage (winterfat)	Eurotia lanata
	Mormon tea	Ephedra spp.

All of the major vegetative types in the area provide good winter forage for sheep or cattle. Exceptions are:

(a) Much of the pinon-juniper has very few forage plants growing underneath.

(b) Some of the big sage brush is in dense, nearly pure stands, which livestock will only use lightly.

(c) The sparse cover on some of the bare shale in the desert shrub and salt desert shrub types provides little, if any, forage.

The vegetation along the Green River and the White River is mainly annuals, desert salt grass (Dictichlis stricta), alkali sacaton (sporobolus airoides), tamerix (Tamarix gallica), willows (Salix spp.), and squaw bush (Rhus trilobata). This type is used mostly by cattle in summer.

The pinon-juniper type produces a few cedar posts and some firewood.

There are several poisonous plants in the unit, but only the following two cause serious problems with livestock: Loco weed (Astragalus spp.) is scattered throughout the area. After a wet, warm, fall it becomes a serious problem to livestock men. Sheep herds must be kept off the area to provent considerable loss.

Halogeton is scattered throughout the unit, and in some disturbed areas forms dense patches. This plant has not caused serious problems in the past, but sheep herds must be managed to avoid it.

The loco weeds and halogeton have their greatest concentrations within the mixed desert shrub areas on the fringes of the pinon-juniper.

Death camas is scattered generally over the entire unit. There are no known concentrations of any consequence within the unit.

Major losses of sheep occured on the loco weeds during the winter grazing seasons of 1957-58 and 1965-66.

9. Recreational Resources

The oil shale areas of the Uinta Basin are extensively used for hunting during a fall hunting season. Small game animals and birds are also hunted. The canyon lands of the Green River are occasionally used for adventurous boating excursions. Fishing potential along the White and Green Rivers where they cross the oil shale land is good but little used.

The oil shale areas of the Uinta Basin are generally little used for other recreational purposes. The more attractive recreational areas which are utilized are in the nearby Uinta Mountains and in Dinosaur National Monument north of the arid flat land of the oil shale area.

The recreation resources in the environs of the Uinta Basin mostly outside of the oil shale area consist of many high quality recreation opportunities of the following types:

(a) Water oriented activities associated with the lakes, ponds, and streams of the Uintah Mountains along the Basin's northern boundary, the Tavaput Plateau on the southern boundary, and the Green and Duchesne Rivers of the lowlands, 138 lakes, ponds, rivers;

(b) Background opportunities of the Yellowstone Creek, Rock Creek and the badlands in the White River area;

(c) Wildlife opportunities, especially those associated with Ouray Wildlife Refuge along the Green River, winter deer range, and deer on ten major hunting units in the Basin, average yield harvests of 8,000 deer annually are common in the Basin;

(d) Winter sports in the Grizzly Ridge Ski and Winter Recreation Area 25 mile north of Vernal.

(e) Sightseeing of unique features and scenic wonders of the Flaming Gorge, Book Cliffs, Sheep Creek Canyon, Whiterocks Fish Hatchery, Grays and Desolation Canyons, and the valley country of the Green and Duchesne Rivers.

(f) Cultural and Historic sites of: Old Fort Duchesne, the Uintah-Ouray Indian Reservation, Desolation Canyon, Sheep Creek Geological Area, Dinosaur National Monument, Indian Petroglyphs in Dry Fork Canyon, and Fort Robideaux.

For recreation planning purposes the State Outdoor Recreation Plan of Utah has designated the counties of Duchesne, Daggett and Uintah as the "Uinta Basin Planning District--Planning District VII."1/ The Bureau of Land Management has designated this same area as the "Vernal District." BLM administers 1,673,000 acres or 31 percent of the Uinta Basin's 5.4 million acres. Most of BLM's lands are located in Uintah County which contains most of the potential high yielding oil shale lands, 768,000 acres. National Forest lands of the Basin are located outside of the primary oil shale lands area. Lands of the Uintah and Ouray Indian Reservation are located immediately adjacent to the primary oil shale lands.

All lands under the administration of the Bureau of Land Management and the Forest Service are generally considered for multiple use, including outdoor recreation. The total acres of designated,

---

1/ Outdoor recreation in Utah--1970.

developed, recreation sites on all Federal and State lands in the Basin is less than 15,000 acres; the potential is estimated to be 4.2 million if we consider only Federal lands under multiple use. The total acreage set aside as recreation sites in the Basin is less than 16,000 acres. Ninety percent of the site acres occur on Federal lands followed by six percent on private lands.

Half of the recreation visitors to northeastern Utah are sightseers or tourists. Fishing and hunting combined account for 24 percent of the visitors followed by camping and picnicking at 16 percent. Deer hunting is known to be the primary type of hunting with 8,000 deer being harvested annually in the Basin. Rock hunting is considered to be a fast growing activity in the Basin. Water sports account for only one percent of the visitors. However, the potential for water oriented activities is high with almost 75 percent of the feature oriented sites in the Basin being related to water; 48 percent are related to streams or rivers, 30 percent to lakes and/or reservoirs.

In 1968 the estimated outdoor recreation visitor-day use in northeastern Utah was estimated to be 1.2 million days or 15 percent of the State total of 7.8 million visitor days. Dagget County, the smallest county by far with only 461,400 acres, accounted for almost half of the Basin's visitor days. However, most of these were to the highly developed Flaming Gorge Natural Recreation Area on the Ashley National Forest, and the Dinosaur National Monument administered by the National Park Service. Uintah County accounted for 35 percent of the Basin's visitors. Duchesne County was far behind with 17 percent.

Applying State of Utah economic day use values of 10 and 15 dollars the estimated 1968 returns to local and State economies of the Basin for outdoor recreation were 11.7 and 17.1 million dollars respectively. For BLM lands in Daggett and Uintah Counties the estimated visitor days and dollars to the local economy was 112,875 days and $1,128, 770; hunting and fishing accounted for 70 percent of the visitor days and monies.

10. Socio-Economic Resources

Access to Uinta Basin oil shale area is gained, from the North, by U.S. Highway 40; and from the south, by U.S. Highway 6 and 50, (Figure IIC-31). Gravel surface State and county roads cross the basin in a general north-south direction. Jeep trails, and seismic and oil exploration roads crisscross the basin in a random manner. Population within the three principal BLM planning units is approximately 470.

The better oil shale area of the Uinta Basin is sparsely populated. A small gilsonite mining community, Bonanza, and a small Indian village, Ouray, lie within the rich oil shale lands. A few gas field development buildings and personnel occupy installations in the oil shale area. Major oil field developments and installations

Table II-13.--Land Ownership and Outdoor Recreation Site Ownership Within the Uinta Basin--1972.

Administering	Total Lands		Recreation Sites	
Agency and Owner	Acres	Percent	Acres	Percent
Federal	4,050,000	75	14,217	90
State	270,000	5	155	1
Local			379	2
Quasi-public			80	1
Private	1,080,000	20	890	6
Total	5,400,000	100	15,729	100

Table II-14. --Estimated Outdoor Recreation on Federal and State Lands in and near Uinta Basin--1968.

County	Approximate Land Area Acres	Visitor Day Use	
		Days	Percent
Daggett*	461,440	550,000	48
Duchesne	2,086,400	210,000	9
Uintah	2,856,320	410,000	35
Total	5,404,160	1,170,000	
State	52,696,960	7,770,000	

*Daggett County, Utah, is situated north of the oil shale region of the Uinta Basin, and south of the oil shale region of Green River Basin, Wyoming.

are situated north of the oil shale area.

The land surface of the oil shale area is used mostly for wildlife range, wildlife refuge, and seasonal livestock grazing.

Vernal, Utah, a town of approximately 4,000 population is in the center of the Ashley Valley, north of the oil shale area. The Valley is 48 square miles in area and supports a population of nine to ten thousand. The primary industries in the Vernal area are oil and mining, agriculture and tourism. The community has a dependable water supply from Ashley Creek and Ashley Springs. The town of Vernal supplies water to the entire Valley through a pipeline system. Vernal is the service center for the Rangely oil field, Ashley oil field and newly developing oil fields in adjacent Duchesne County. It is also the center for a phosphate mining enterprise 12 miles from the town and the Gilsonite Mines at Bonanza, Utah.

Vernal and Uintah County maintain a planning commission, which has developed a planning and zoning program for the entire County. The community has an adequate school system. The city maintains a 30-bed hospital, which is being enlarged to 50 beds. There is presently an acute shortage of physicians in the town. Vernal is located on U.S. Highway 40, a major east-west artery. It has no railroad but maintains an airport facility with a 6,000 foot runway.
Frontier Airlines provides service principally to Denver, Salt Lake City, and Grand Junction.

The town has many tourist attractions, including the nearby Dinosaur National Monument, an outstanding geological museum, and excellent fishing, hunting and camping facilities in nearby national forests and the Flaming Gorge Reservoir Recreation Area. Nearby agricultural enterprises are primarily large livestock ranches with small acreages of irrigated hay and pasture lands in the drainage bottoms.

The counties in Utah in the Uinta Basin which will be most directly affected by oil shale development are Duchesne and Uintah.

The Uinta Basin and its surrounding counties has the least population of the three oil shale regions. The population of the two counties was just 20,000 in 1970. Uintah County accounted for 60 percent of the total, and Vernal with a population of 4,000, accounted for one-third of the Uintah County total in the same year. Median family income for the two counties in 1970 was $7,893, while for the city of Vernal it was $9,242. Both median income and the median number of school years completed were higher in the city.

In 1962, the local governments of Uintah and Duchesne counties expended a combined total of $4.2 million including $2.8 million for educational purposes, $0.4 million for highway maintenance and construction and $0.11 million hospital services. Total revenue of the combined area in the same year was $4.3 million.

Table 15 - County and City Social Characteristics, 1970 -- Utah 1/

	Population (1,000)	No. of Households (1,000)	School Enrollment Primary (1,000)	School Enrollment High School (1,000)	Median School yrs. completed (25 yrs. & over)
Duchesne County	7.3	2.0	1.6	.8	12.1
Uintah County	12.7	3.4	3.0	1.1	12.3
Total	20.0	5.4	4.6	1.9	12.2
City of Vernal (Uintah Co.)	4.0	1.2	.9*	.4*	12.6

*estimated

1/ Source: 1970 Census of Population, General Social and Economic Characteristics-Utah, U. S. Department of Commerce, Washington, D.C., 1972

Table II-16.--County and City Economic Characteristics, 1970 -- Utah 1/

	Employment					
	Total Employed 16 yrs. & over (1,000)	White Collar & Service (1,000)	Blue Collar & Service (1,000)	Agricultural (1,000)	Percent Unemployed	Median Family Income
Duschesne County	2.4	1.1	.9	.4	4.6%	$7,572
Uintah County	4.0	1.6	2.0	.4	7.0%	8,082
Total	6.4	2.7	2.9	.8	6.1%	7,893
City of Vernal (Uintah Co.)	1.4	.8	.6	**	6.0%	9,242

**less than 50

1/ Source: 1970 Census of Population, General Social and Economic Characteristics-Utah, U. S. Department of Commerce, Washington, D.C., 1972.

Table 17 . County Economic Indicators, Government -- Utah[1]

Local Government Finances[2]

County	Revenue: Total Mill $	Revenue: Property Tax Per Capita $	Expenditures: Total Mill $	Expenditures: Education Mill $	Expenditures: Highway Mill $	Expenditures: Health and Hospital Mill $	Expenditures: Other Mill $
Duchesne	1.5	74	1.4	1.0	.1	.01	.3
Uintah	2.8	112	2.8	1.8	.3	.1	.6
Total	4.3	95	4.2	2.8	.4	.11	.9

1- Source: County & City Data Book, 1967, U. S. Bureau of Census, Washington, D.C., 1967.

2 - 1962

Table 18 - County Economic Indicators, Private -- Utah[1]

County	Retail Trade[2]		Services[2]		Agriculture[3]		
	Total Establishments	All Sales Mill $	Total Establishments	All Receipts Mill $	Acreage Farmed (1,000)	Total Commercial Farms	Value of Farm Products Sold Mill $
Duchesne	94	8.0	51	1.0	522	448	4.7
Uintah	127	16.0	93	1.8	1123	342	3.7
Total	221	24.0	144	2.8	1645	790	8.4

1 - Source: County & City Data Book, 1967, U. S. Bureau of Census, Washington, D.C., 1967.
2 - 1963
3 - 1964, preliminary

Revenue collected by the Uintah County Government was about two-thirds of the two-county total, $2.8 million.

Uintah County, which has twice the population of Duchesne County, is also twice as large in the categories of total employment, retail sales, and value of services. In value of petroleum production Uintah is three times as large as Duchesne. In value of farm products sold, however, Duchesne County exceeds Uintah with only half as many acres utilized.

The major portion of both Duchesne's and Uintah County's mineral production is oil production. In 1970 the value of petroleum produced in Duchesne County was $5.3 million and the industry employed 86 people. The oil industry in Uintah County employed 715 people and production was valued at $17.6 million which was just under two thirds of the county's total mineral production value.

11. Archaeological and Historical Values

There are no historic sites listed for Uintah County, Utah in the National Register of Historic Places.

The Colorado Historical Society recognizes the historic significance of the abandoned Uintah Railroad and related sites located along the Colorado - Utah State Line.

The White River area in Utah has the highest values. Two rock overhangs with evidence of the Fremont culture, a farming group of Indians dating in the 11th Century A.D., were found within one-half mile of the White River at the County Bridge crossing and others may be expected along with possibly some pithouse village sites in the rest of the main canyon and near the mouths of the watered side canyons emptying into the White River.

Historical sites of importance are also present in the White River vicinity in the area immediately adjacent to the proposed use area. These are at the road crossing of the White River (Ignacio Stage Stop and Old Bridge) and in the Gilsonite mining area. The ghost towns of Rainbow and Watson, the remains of the narrow gauge Uintah Railroad which served the area until 1938 and the remains of many abandoned old gilsonite mines, an interesting relic of a rare mineral activity, are all adjacent to the south boundary of the potential development area. All of these sites are off the proposed lease areas.

12. Land Use

The generally semi-arid and severe climatic nature of the area limit any cultivation of new lands for crop production. Most of the lands having agricultural potential are along the stream valleys and are already in private ownership. Vernal is the nearest population and community center. Any expansion of population and accompanying development is expected to take place in Vernal or other established communities.

13. Land Status

The total land area in the three principal BLM planning units involved is 1,091,959 acres. Land ownership in the three units is:

BLM Planning Unit	% Federal	Public Land Acres	State Acres	Private Acres
Bonanza	82.5%	337,518	46,295	19,278
Rainbow	77%	299,424	52,259	37,874
Book Cliff	82%	239,971	36,652	17,112

D. Wyoming (Green River and Washakie Basins)

1. Physiography

The Wyoming oil shale deposit areas are bounded on the west by the Wasatch Mountains; on the north by the Wind River Range, the Green Mountains and Seminoe Mountains; on the east by the Medicine Bow Range; and on the south by the Uintah Mountains. This area of southwestern Wyoming includes all of Sweetwater, and part of Lincoln, Sublette, and Carbon Counties. The area of principal concern, however, is that portion of Sweetwater County which contains the richest and thickest deposits of oil shale. The best oil shale lies within the Green River structural basin. Good quality oil shale also underlies the western part of the Washakie Basin. (See Figure II-1 and II-3.)

The best deposit of oil shale (Green River Basin) is cut west to east by Interstate Highway 80 and north to south by U.S. Highway 187. (Figure II-21.) Jeep trails and mineral exploration roads in the area are numerous.

The Green River is the principal flowing water source in the immediate area, with the Big Sandy furnishing the only other source of live water. Drainage of the area flows into these two streams.

Topography is structurally controlled, varying from synclinal valleys to monoclinal slopes, with hills and ridges having a steep face on one side and a gently sloping face on the other side. This is illustrated in Figure II-33; an aerial view of the Kinney Rim area. Elevations range from about 5,000 to 8,000 feet. Badlands are common in some of the soft mudstone of the area's Bridger Formation.

The area is generally underlain by soft shales and fine grained sandstone of Cretaceous and Tertiary age. Weathering of these beds and stream transport of material have filled the valleys along major streams with alluvium.

Figure II - 33 Aerial View of Oil Shale Exposure in Kinney Rim, Washakie Basin, Wyoming.

2. Climate

Annual precipitation in the Wyoming oil shale area varies from approximately 7 to 21 inches, considerably less than surrounding highlands; consequently the area is considered semiarid.

Seasonal distribution of precipitation is variable, but the annual total precipitation changes little from year to year. Winters are cold, summers short and hot. Most of the precipitation comes as winter snow. The relatively dry summers have occasional thunderstorms with rapid runoff.

The temperature range in the area is extreme. Summer temperatures may reach 90 degrees F. and winter temperatures can drop to -40 degrees F. July is usually the hottest month and January the coldest. Temperatures within the area vary considerably. The frost-free season varies from 50 days to 120 days.

Winds are relatively strong over the areas which is typical of semi-arid regions.

3. Geology

The principal oil shale leasing areas underlying 6700 square miles in south western, Wyoming are in the Green River Basin and Washakie Basin. Oil shale beds are exposed in ledges and low escarpments along the eastern margin of the Green River Basin and along the western margin of the Washakie Basin. The oil shale zones in the Green River Formation extend below surface to depths as much as 3,000 feet or more.

Several members of the Green River Formation intertongue with sandstone - mudstone Members of the Wasatch Formation. In the Central parts of the basins the oil shale bearing rocks are overlain by the Bridger Formation. The details of distribution of the oil shale and related rocks are shown in maps by Bradley (1964, plate 1.) Culbertson (1969 p.192), and Roehler, (1969, p. 197.)

The reader is referred to their reports for maps, cross sections and discussion of details of the deposits.

The general stratigraphic distribution of oil shale and sodium minerals of the Green River Basin are shown in Figure II-34. The distribution and character of rocks in the Washakie Basin are shown in Figures II-35. and II-36.

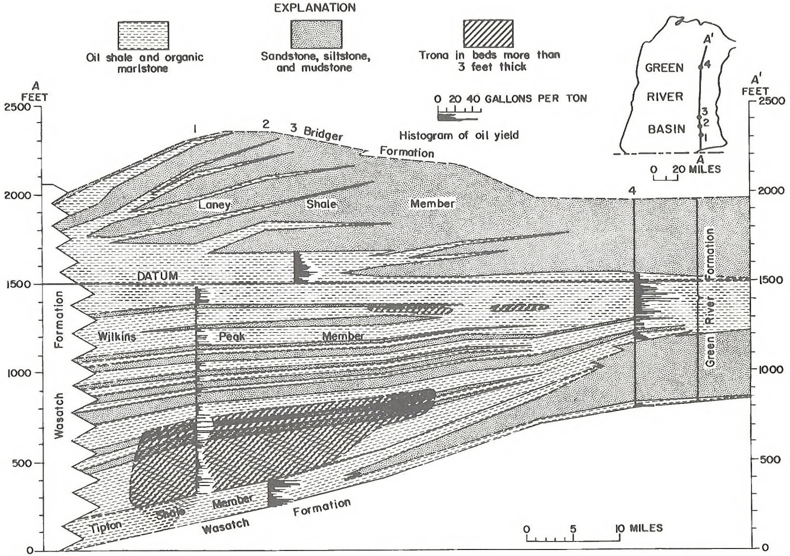


Figure II - 34 Cross Section of Green River Formation in Green River Basin, Wyoming

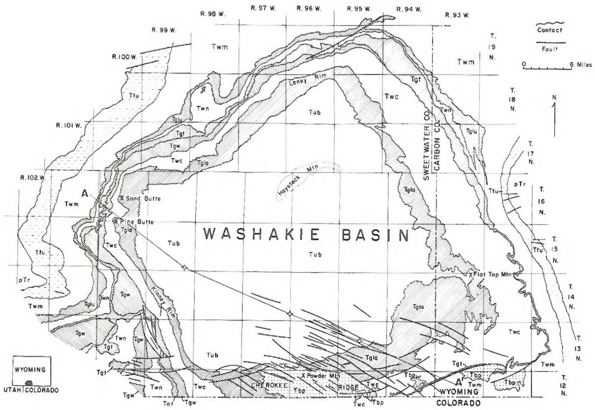


Figure II - 35 Geologic map of the Washakie Basin, Wyoming

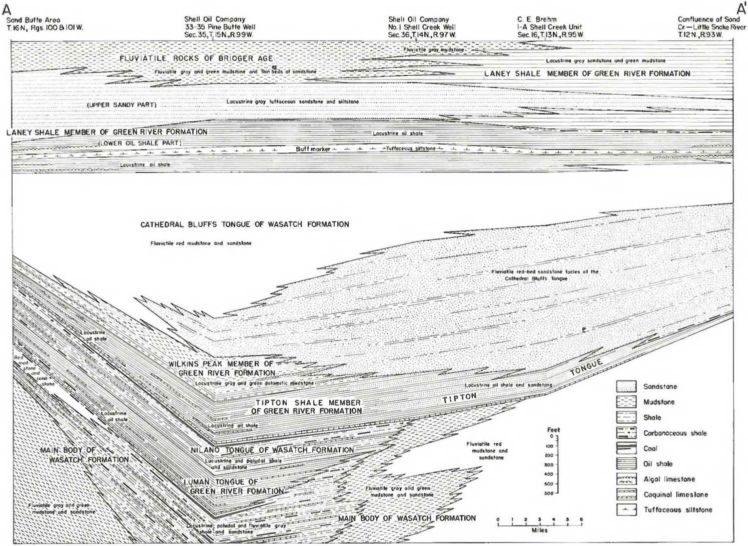


Figure II - 36 Simplified restored section of the Wasatch and Green River formations in the Washakie Basin, Wyoming

More than 20,000 feet of older sedimentary rocks underlie the Green River Formation in the Green River Basin. These older sediments locally contain oil and gas reservoirs which are produced in the Church Buttes, and Big Piney gas fields. Other smaller fields are shown in Figure II-6

Coal bearing rocks are also deeply buried beneath the Green River Formation, (Figure II-7).

a. Stratigraphy

The Green River Formation in the Washakie basin is divided into four units:

Laney Member -- The Laney Member attains a thickness of more than 1,300 feet in the basin. The uppermost two-thirds of the member consists in great part of gray and brown sandstone and siltstone, in part tuffaceous, and thin beds of limestone that in places are algal. There are also a few thin beds of low-grade oil shale in the lower part. The lower one-third of the member consists mostly of oil shale of varying value. A buff to gray tuffaceous siltstone and mudstone bed 50 to 60 feet thick, near the middle of the unit, separates the oil-shale sequence into two zones. The upper oil-shale unit is somewhat thicker and in general richer than the lower one.

Wilkins Peak Member -- The member is about 400 feet thick and may be divided into two approximately equal units. The upper unit consists mainly of gray or brown mudstone, siltstone, or sandstone, and minor amounts of thin-bedded oolitic and algal limestone and thin beds of low-grade oil shale. The lower unit consists almost entirely of low-grade oil shale with some beds of moderately rich oil shale, algal limestone, and siltstone. The Wilkins Peak Member is separated from the Laney Member by more than 1,500 feet of varicolored mudstone, sandstone, and siltstone in the Cathedral Bluffs Tongue of the Wasatch Formation.

Tipton Member -- The Tipton Member immediately underlies the Wilkins Peak Member, is about 200 feet thick, and consists almost entirely of low-grade to moderately rich oil-shale with a few thin algal limestone and siltstone beds. The oil shale in the upper half is considerably richer than that in the lower half.

(1) Luman Tongue.-The Luman Tongue is the lowermost unit in the Green River Formation. It is about 300 feet thick and the upper half consists almost entirely of low-grade oil shale with a few thin-bedded limestones. The lower half consists of interbedded siltstone, sandstone, mudstone, low-grade oil shale, thin moderately rich oil shale, fossiliferous limestone, carbonaceous shale, and coal. The Luman is separated from the Tipton by about 200 feet of interbedded siltstone, sandstone, mudstone, low-grade oil shale, thin moderately rich oil shale, fossiliferous limestone, carbonaceous shale, and coal in the Niland Tongue of the Wasatch Formation.

b. Structure

The Washakie basin is essentially a large northeast-trending syncline. The main synclinal feature is modified in places by subsidiary structures.

The center of the Washakie basin is essentially fault free. Intensity of faulting is greatest along the southern margin of the basin. In this area the southernmost faults trend west parallel to Cherokee Ridge, a structural high that bounds the Washakie basin on the south. North of the west-trending faults are a series of northwest-trending normal faults as much as 10 miles in length that extend from the Wasatch Formation outcropping on the southern margin into the lowermost part of the rock sequence overlying the Green River Formation that outcrops near the center of the basin. The west margin of the basin is less heavily faulted; however, there are some north to northwest-trending normal faults along the west margin that are less than 6 miles in length. The northwestern, northern, and northeastern parts of the basin are essentially fault free.

4. Mineral Resources

a. Oil Shale

Recently the U.S. Bureau of Mines drilled two core holes near the western margin of the Washakie basin. This is the only core assay information publicly available from the Washakie basin and was deemed to be insufficient for a reliable estimate of the oil-shale resources of the entire Washakie basin.

b. Other Minerals

Thus far, sodium minerals in or associated with the oil-shale deposits in other basins have not been found in or with the oil shales in the Washakie basin. Both oil and gas, in commercial quantities, has been produced from the Wasatch, Fort Union, and Mesaverde Formations in fields surrounding the Washakie basin. These producing formations underlie the basin. The producing zones in the Fort Union and Mesaverde Formations are several thousand feet below the lowermost oil shales in the Green River Formation.

Coal deposits also are present below the oil shale bearing rocks. They are so deep they are not considered usable in the for-seeable future.

5. Water Resources

a. Surface Water

The Green River is the principal surface water resource of the Green River Basin. Records from the stream flow station on the

Green River near Green River, Wyoming, show a 19-year mean discharge of 1620 cubic feet per second. Dissolved solids concentration (18 years of record) ranged from 156 to 855 mg/1, with a discharge - weighted mean of 303 mg/1.

Streams draining the oil shale land in the Green River and Washakie Basins receive very little precipitation each year and only flow intermittently. It is doubtful whether much local surface water could be developed within the area. Up to 150,000 acre feet of water annually could be made available from the Green River for development of oil shale in the Green River and Washakie Basins. This could be made available from the existing Fontenelle and Flaming Gorge Reservoirs-Additional water in the areas could be made available by purchasing and changing the nature of use and point of diversion of existing senior water rights."

b. Ground Water

In the Washakie Basin near Kinney Rim, ground water occurs above, below and probably in the oil shale, and deep water is under artesian pressure. Checmical quality of the ground water in the Laney Member near Kinney Rim is good, having a dissolved-solids content of less than 1,000 mg/l. No data on water quality of the deeper beds are available. Transmissivities are probably very low and the Green River Formation in the Washakie Basin contains probably much less water in storage than in the Piceance Basin.

In the Green River Basin, the Green River Formation generally contains water under artesian pressure. The maximum yields of existing wells range from about 1 to 500 gpm, but the yield of most wells range from about 10 to 100 gpm. Yields greater than 500 gpm of water of unknown quality but probably saline, could probably be obtained from deep wells (2,000 to 5,000 feet) penetrating thick sandstone sections in the Wasatch and Fort Union Formations beneath the oil shale. (Welder, 1968). The dissolved-solids content of ground water in the Green River Formation ranges from less than 500 to more than 3,500 mg/l. The amount of ground water in storage may approach that of the Piceance Creek Basin, Colorado, but probably very little is feasibly recoverable.

6. Wildlife and Fish

The Green River Basin oil shale lands possess significant fish and wildlife values. High quality game habitats consisting of varied associations of browse and grass species provide forage requirements for significant populations of deer, elk and antelope. In addition, the area contains thriving populations of blue grouse, sage grouse, chuckars, doves, rabbits, coyotes, bobcats, as well as various species of waterfowl, raptors, and the numerous other small bird and mammal forms expected in an ecologically healthy high-desert range area. Wild horses are quite numerous throughout general range areas, and a number of threatened species, including the mountain lion, bald eagle and golden eagle are dependent upon habitat within the Green River Basin. The major wildlife and fish resources are as follows:

a. Big Game

An annual average harvest of approximately 5,000 mule deer are taken by about 8,000 hunters. A small population of black bears is found in the area. The Wyoming Basin is one of the State's most important antelope habitat and harvest areas, supporting a high density population. Approximately 1,500 hunters harvest approximately 1,300 antelope annually. Several small herds of elk exist in the oil shale areas including: one in the sand dune area east of Eden; one in the Pilot Butte area; and one in the southern portion of the Pine and Little Mountain area. These animals range over portions of the tri-state area, and hunting seasons are provided in all three States. These are important elk range areas, north, west, and south of Kemmerer, Wyoming. A limited herd of Shira moose occupy the riparian oil shale lands along the Green River and its tributaries. In 1969, 36 hunters harvested 32 animals. Mountain lions occur in a rather even density over the Wyoming oil shale lands. No data are available on the existing number of this species.

It is estimates that about 300 wild horses inhabit the Wyoming oil shale lands.

b. Small Game

No reliable data are available on distribution or densities of small game in the area. However, the cottontail, coyote, and fox are regarded as common.

c. Small Game Birds

The Wyoming Basin is an important sage grouse area with the Eden Farson area exhibiting one of the highest densities of this species known to exist. In 1969, 7,776 hunters spent 17,843 recreational man-days harvesting 39,876 sage grouse. Ruffed grouse, blue grouse, and chukar are sought by around 300 hunters annually, and the harvest for each of these species varies from 200-700 birds per year. In 1969, it is estimated that about 8,000 ducks and 795 geese were bagged in the limited available habitat along the Green River.

d. Fish

The Flaming Gorge Reservoir and the Green River are the major sport fisheries areas in the oil shale lands. Flaming Gorge Reservoir is considered to provide excellent angling, and in 1970 it was reported to provide 232,000 anglers with 367,000 fish. The Green River provides a fair to good trout fishery. The section from Big Island to Fontonelle Reservoir provided an estimated 4,700 trout in 1970, while the section from Big Island to the Kincaid Ranch provided an additional 3,525. The Bear, Hams Fork, and Little Snake Rivers are considered to vary from fair to poor in angling quality. The Little Snake River from Baggs to Savory is fair with good potential for improvement. The upper reaches of the Little Snake River have been dedicated to the preservation of the Colorado River cut-throat trout.

Although little data are available on the sport fishery resource in the smaller streams, some of the more significant trout habitat exists in headwater streams in the oil shale area.

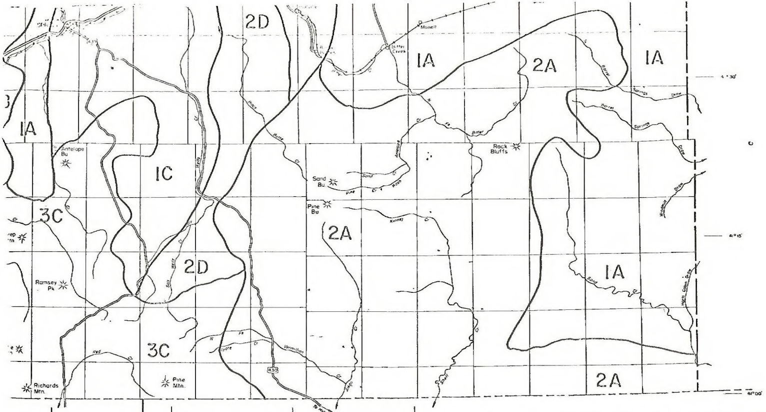
7. Soils and Vegetation

The soils of the Washakie Basin (Figure II-37) are classified as Haplargids, Torriorthents and Salorthids. They are developed on the high dissected plateaus of the Green River, Bridger, and Wasatch Formations. Slopes range from nearly level, moderately sloping (75 percent of the basin), to steeply sloping (20 percent of the Basin). Soil textures vary from sandy, loamy to clayey.

Sixty percent of the soils in the Basin are estimated to be shallow, less than 20 inches to bedrock; the remainder of the soils are moderately deep to deep. Erosion hazards are generally moderate to high, wind erosion is more of a problem than water erosion because of the low rain fall 10 to 14 inches. Soil reaction is commonly alkaline to strongly alkaline.

Land types such as Shale badlands and sand dunes also occur in the Basin.

Vegetation consists of grass and desert shrubs, including



GENERAL SOIL MAP

SWEETWATER COUNTY

(PORTION - Oil Shale Tracts)

WYOMING

OCTOBER 1970

5 0 5 10 15

SCALE 1:500,000

This map is intended for general planning. Eac delineation may contain soils different from those shown on the map. Use detailed soil maps for oper ational planning, and on site inspection for more detailed decisions.

Soils of Residual Uplands: Elevation 7,000 to 8,000 feet:
Precipitation 10 to 14 inches

2A Washakie Basin; Delaney and Kenney Rims
2B Pilot Butte-White Mountain-Fire Hole Canyon
2C Lost Soldier-Twin Buttes
2D Black Buttes
2E Batrum-Bison Basin

Figure II - 37

belts of mesophytic shrubs. There are three distinct vegetative types, of which the sagebrush steppe (Artemesia-Agropyron) is the major. Juniper-pinon woodland if found on the higher knolls, hills, and north slopes, and salt-bush greasewood in the flats of some of the drainage basins.

8. Recreational Resources

In the oil shale area of the Washakie Basin the primary outdoor recreation activities are oriented towards fall hunting. (Mostly antelope and deer, and game birds).

In the environs around the oil shale land there are other recreation opportunities. The State Outdoor Recreation Plan for Wyoming has designated all of Sweetwater County as part of the State's Recreation Region 7, (R7).[1/] Other countries in R7 include Sublette, Lincoln and Uinta. All of these counties contain potential oil shale lands which could have an effect on outdoor recreation.

Recreation inventories of Sweetwater County show that the potential for outdoor recreation activities such as: big and small game hunting, camping, natural and scenic areas, cold water fishing, and vacation ranches is high; for warm water fishing, winter sports and pack trips it is low; while for water sports, picnicking and water fowl it is medium.[2/] With 6.7 million acres in Sweetwater County, Federal agencies administer 4.5 million acres or 68 percent of the recreation potential of the county, State and local agencies 346,280 acres or 5 percent, and private owners 1.8 million acres or 27 percent.

Of the 13 Federal recreation areas reported to the Bureau of Outdoor Recreation in the 1965 inventory of designated public

1/ An Outdoor Recreation Plan for Wyoming--1970.
2/ Outdoor Recreation Potential Wyoming--1969, USDA, SCS.

recreation areas for Sweetwater County, 12 are administered by BLM, one by the Forest Service, Flaming Gorge Recreation Area. The State of Wyoming reported one State park area.3/

Hunting, fishing and camping were the activities most often sought after by the 700,000 who visited BLM lands in 1965. Approximately 125,000 visits were made to the Pine Mountain, Bitter Creek and Burntfork Recreation complexes which are the closest to the Washakie Basin; 18,000 of these visits were campers.

Private outdoor recreation enterprises in Sweetwater County consists of six entrepreneurs on only 1,153 acres; two operate camping grounds, one provides natural and scenic facilities, one operates a vacation ranch, and the other two are urban oriented.

3/ Bureau of Outdoor Recreation Survey of Public Areas and Facilities, 1965.

Table II-19.--Attendance at Public Outdoor Recreation Areas in Sweetwater County--1965.

Agency	Visits Day	Visits Night
Federal		
NPS		
Flaming Gorge Recreation Area	149,946	19,830
BLM Recreation Complex		
Bitter Creek	85,000	15,000
Burntfork	22,000	3,000
Flaming Gorge	325,000	75,000
Granger	8,000	2,000
Leucite Hills	45,000	5,000
Little Colorado	27,000	3,000
Northeast	175,000	25,000
Pilot Butte	17,000	3,000
Pine Mountain	175	25
Red Desert	1,800	200
Seven Lakes	900	100
Total	706,875	131,325
State		
Big Sandy Reservoir Area	9,880	1,490

9. Socio-Economic Resources

The oil shale area of the Washakie Basin, is essentially uninhabited except by temporary users of the area. The Basin is situated southeast of Rock Springs in Sweetwater County and is accessible by several unimproved dirt roads.

The 1970 population of Sweetwater and Uintah Counties was 25,400. Sweetwater, the larger of the two, had nearly 75% of that total. Its county seat, Rock Springs, with a population of 11,700, accounted for 63% of Sweetwater County's total population. The two-county area had a total of 7,900 households with 49% (or 3,900) located in Rock Springs. The median family income for the area was $9,064 during 1970.

Rock Springs is the largest community in the two-county area, located approximately 40 miles northwest of the nominated tracts. Access to the community is provided by Interstate 80, a major east-west artery, the Union Pacific Railroad and Frontier Airlines.

Though the area is considered rural and isolated by national standards, agriculture is not its economic mainstay. Of the total region's employed persons, 9,700, only 5% were employed in the agricultural sector. A little more than half the area's total employed persons are blue collar and service workers.

The economic structures of the counties and city appear to be relatively stable. In 1962 general revenue for the Sweetwater County government was $4.48 million. Almost half of the expenditures were for the local school system. At present, the school system is considered adequate to meet present needs. Rock Springs has a two-year community college. In 1962, the county also expended $696,000 for health and hospital services. The community has a 100-bed hospital.

The economic base of the area is agriculture (large livestock ranches), mineral extraction, and tourism and recreation. Present development includes a 300,000 kilowatt steam electric plant being constructed by the Pacific Power and Light Company. The plant is expected to add 1200 people to the community of Rock Springs.

Sweetwater County is more heavily dependent upon the minerals sector for economic support than Uinta County. The value added by mining in Sweetwater County was fifteen times as great as the value of farm products, while in Uinta County mining values were less than half those of agricultural sales.

Table 20 .-- County and City Social Characteristics, 1970 -- Wyoming 1/

	Population (1,000)	No. of Households (1,000)	School Enrollment Primary (1,000)	School Enrollment High School (1,000)	Median School yrs. completed (25 yrs. & over)
Sweetwater County	18.3	5.9	3.5	1.3	12.2
Uinta County	7.1	2.0	1.3	.6	12.2
Total	25.4	7.9	4.8	1.9	12.2
City of Rock Springs (Sweetwater Co.)	11.7	3.9	2.1	.8	12.2

1/ Source: 1970 Census of Population, General Social and Economic Characteristics-Wyoming, U. S. Department of Commerce, Washington, D.C., 1972.

Table 21 .-- County and City Economic Characteristics, 1970 -- Wyoming 1/

	Employment					
	Total Employed 16 yrs. & over (1,000)	White Collar & Service (1,000)	Blue Collar & Service (1,000)	Agricultural (1,000)	Percent Unemployed	Median Family Income (dollars)
Sweetwater County	7.0	2.9	3.9	.2	4.4%	$9,077
Uinta County	2.7	1.0	1.4	.3	4.6%	9,025
Total	9.7	3.9	5.3	.5	4.4%	$9,064
City of Rock Springs (Sweetwater Co.)	4.5	2.1	2.3	.1	4.4%	$8,970

1/ Source: 1970 Census of Population, General Social and Economic Characteristics--Wyoming, U. S. Department of Commerce, Washington, D.C., 1972.

Table 22 .- County Economic Indicators, Government -- Wyoming[1]

County	Local Government Finances[2]						
	Revenue		Expenditures				
	Total Mill $	Property Tax Per Capita $	Total Mill $	Education Mill $	Highway Mill $	Health and Hospital Mill $	Other Mill $
Sweetwater	4.5	113	4.5	2.0	.4	.7	1.4
Uinta	1.6	93	1.8	1.0	.1	.2	.5
Total	6.1	107	6.3	3.0	.5	.9	1.9

1 - Source: County and City Data Book, 1967, U.S. Bureau of Census, Washington, D.C., 1967
2 - 1962

Table 23!.- County Economic Indicators, Private -- Wyoming[1]

County	Retail Trade[2]		Services[2]		Agriculture[3]		
	Total Establishments	All Sales Mill $	Total Establishments	All Receipts Mill $	Acreage Farmed (1,000)	Total Commercial Farms	Value of Farm Products Sold Mill $
Sweetwater	259	29.0	138	5.9	426	111	3.0
Uinta	109	9.9	52	1.0	737	217	2.8
Total	368	38.9	290	6.9	1163	328	5.8

1 - Source: County and City Data Book, 1967, U.S. Bureau of Census, Washington, D.C., 1967

2 - 1963
3 - 1964, preliminary

10. Land Ownership

In Sweetwater County including most of the oil shale land, ownership is as follows:

County	% Federal	Public Land (Grazing Dist.) Acres	Reserved Public Lands	State Acres (Approx.)	Private Acres (Approx.)
Sweetwater	69%	2,130,328	2,244,302	140,200	1,687,000

11. Land Use

The dry climate and limited growing season permit only the growth of alfalfa hay, native hay, and some small grains along some of the major drainages, and at the Eden Reclamation Project.

The area is grazed by livestock for most of the year. Cattle graze the area primarily in the spring, summer, and fall, and sheep primarily in the fall, winter, and spring. Antelope and deer also use the area throughout the year.

Some of the public oil shale lands are also leased for oil and gas exploration and development and for trona production. Some accommodation between different lessees will be required when the oil shale is developed.

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Main Report
Appendix IV - Economic Base and Projections
Appendix V - Water Resources
Appendix VI - Land Resources and Use
Appendix VII- Mineral Resources
Appendix VIII-Watershed Management
Appendix X - Irrigation and Drainage
Appendix XI - Municipal and Industrial Water
Appendix XII- Recreation
Appendix XIII-Fish and Wildlife
Appendix XV - Water Quality, Pollution Control and Health Factor

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III. ENVIRONMENTAL IMPACT

An evolving oil shale industry would produce both direct and indirect changes in the environment of the oil shale region in each of the three States of Colorado, Utah, and Wyoming, where commercial quantities of oil shale resources exist. Many of the environmental changes would be of local significance while others would be of an expanding nature and have cumulative impact. These major regional changes will conflict with other physical resources and uses of the land and water involved. Impacts would include those on the land itself, the water resources and the air quality, on fish and wildlife habitat, on grazing and agricultural activities, on recreation and aesthetic values, and on the existings social and economic patterns as well as others (see Table III-1). These environmental impacts are individually assessed for their anticipated direct, indirect, and cumulative environmental effects in the sections to follow.

The rate at which oil shale may be developed provides the framework within which these evaluations may be made. However, it is impossible, at this time, to determine precisely how an industry would grow to a maximum production capacity of 1 million barrels per day by 1985 from both public and private lands.

The rate at which oil shale may be developed depends on a number of constraints whose relation to each other will change over time. Key factors which must be considered are: (1) technology, (2) resource availability, and (3) water availability.

Technology for mining and surface processing of oil shale has been advanced to the 1,000 ton per day prototype stage of operations as described in the preceding chapter I. The next logical step is commercial operations with each retort in the complex capable of processing about 10,000 tons per day of oil shale. A minimum sized commercial complex would produce 50,000 barrels per day of shale oil; this could be as high as 100,000 daily barrels. At these production rates, the total capital required would range from $250 million to $500 million. The return on this investment is only marginally attractive at 10 to 13 percent on a discounted cash flow basis.[1/] Thus, the initial development of this industry will depend on the availability of large amounts of venture capital which can only be expected to yield a minimum acceptable return on the investment.

As discussed in subsequent sections of this analysis, ample water is available to support the 1 million barrels daily production rate. Estimates of the ultimate size of the industry based upon water availability range from 3 to 5 million daily barrels of shale oil. The ultimate size, however, is quite dependent on evolving technology. For example, sucessful development of in situ production technology would significantly lower water requirements by eliminating the use of water in spent-shale disposal. Heated pipelines and/or improved

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1/ Assumes a present market value of $3.90 per barrel (1).

retorting technology may also eliminate the need to upgrade the crude shale oil produced from surface retorts, thus less water would be required for hydrogen production and related processing such as coking. Such potential future developments make the size of any future development highly speculative at the present time. However, the industry cannot develop beyond the 1 million barrel level without additional public lands. These will not be made available without the preparation of another environmental impact statement that relates specifically to this larger development. The results from the proposed prototype development would provide the firm data upon which to assess the potential impacts of any enlarged program.

For the purpose of this analysis, order-of-magnitude estimates have been made using the following assumptions:

1. The size of the industry could be no more than 1 million barrels per day by 1985.

2. Increased production above 1 million barrels per day would require public lands in addition to those anticipated under the proposed prototype leasing program.

3. Additional public lands will not be offered for development without a thorough review of the expected impact as compared to the actual impact.

4. The detailed calculations given in volume III of this analysis are applicable to the larger development.

Table III-1. - Major impacts of oil shale development.

Major Impacts	Nature of Effect: Direct	Nature of Effect: Indirect
1. Physical Resources		
Land		
Surface disturbance	x	
Erosion	x	
Spent shale	x	
Chemical waste	x	
Trash and other	x	
Soil	x	
Forage	x	
Timber	x	
Other minerals	x	
Landscape, asthetics	x	
Water		
Water quality	x	x
Water supply & aquifers	x	
Subsidence effects		x
Air		
Dust	x	
Plant emissions	x	
Recreation		
Disturb. use		x
Wilderness		x
Fish and Wildlife		
Habitat	x	x
Fishing		x
Hunting		x

Table III-1. (continued)

Major Impacts	Nature of Effect: Direct	Nature of Effect: Indirect
2. Socio-Economic		
Cultural		
Historic		x
Archeological	x	
Social		
Living patterns		x
Population		
In-migration		x
Concentration		x
Economic		
Jobs	x	
Income	x	
Capital flow	x	
Health & Safety		
Plant hazard	x	
Other accident	x	
Pipeline & transp.	x	
3. Government		
Services	x	
Taxes	x	
Title conflicts	x	
Public land use		x
State & other		x

5. The mix of technologies that may be employed from 1981 to 1985 are similar to those that could be used to develop the prototype tracts

6. Other assumptions as noted in the text.

A possible schedule of development is given in Table III-2. Seven installations with a combined capacity of 400,000 barrels per day are assumed to be constructed on private and public lands over the period 1973 through 1981. From 1982 through 1985, capacity is assumed to increase at a rate of 150,000 barrels per year from new facilities at indeterminate locations. This output would be attained through second generation processing systems; therefore, it is assumed that the scale of these later operations would be larger than during development of the prototype tracts. The mix of technology to be used after to 1981 includes five underground mines, one surface mine, and one in situ project.

Subsequent sections of this chapter detail, where possible, the quantifiable effects of the development schedule of Table III-2.

A. Impact on Land

The principal changes on the lands of the oil shale region as a result of commercial oil shale development, are those directly involved with the amount and kinds of surface disturbances resulting from activities on and near the lease tracts, and the accompanying effects on the existing soils, vegetation and topographic and watershed characteristics. In addition, the increased urbanization of the

Table III-2. - Projected Shale Oil Capacity - Cumulative

(Thousands of Barrels per day)

	Colorado Public land	Colorado Private land	Utah Public land	Wyoming Public land	Total
1973	--	--	--	--	--
1974	--	--	--	--	--
1975	--	--	--	--	--
1976	--	50	--	--	50
1977	--	50	--	--	50
1978	50	100	--	--	150
1979	150	100	--	--	250
1980	150	100	50	--	300
1981	150	150	50	50	400
1982					550
1983					700
1984					850
1985					1,000

region will alter limited surface areas in the vicinity of population centers as they grow with population influx. All oil shale mining activities, whatever their nature, will alter a certain volume of the subsurface strata, the amount being dependent upon the type of mining or in situ activity involved.

In Chapter I of this volume, the various processing options for producing shale oil from oil shale were discussed in detail. Either underground mining or surface mining could be used in conjunction with surface retorting and upgrading of the shale oil produced. Alternatively, in situ retorting, may be used with a somewhat lesser amount of surface processing. Various options for processed shale disposal were shown to exist. Roads and utility and pipeline corridors of varying lengths would be needed, depending on lease site location.

This section is concerned with the impacts on the land itself which would result from processing activities, and the accompanying effects on the associated soils, vegetation, watersheds, and topography as industrial development grows throughout the region. The changes which would probably occur in existing patterns of land use are described in later sections.

1. Impact on the Land by Core-Drilling

Core-drilling is frequently a necessary pre-leasing step to aid in resource evaluation, and may be a post-lease-issuance activity as well. A core-drilling site may temporarily disturb from 3 to 15 acres of surface, depending on the size of the equipment involved. To date, about

360 core samples of oil shale have been obtained from 242 locations in Colorado, 73 in Utah, and 45 in Wyoming. Equipment capabilities, personnel, and the amount of surface areas required for typical coring operations in the three State area are as follows:

	Large rig	Small rig
Equipment capabilities, feet	To 8,000	To 4,000
Personnel required, number	10 - 15	4 - 6
Amount of surface area disturbed, acres	10 - 15	3 - 5

The diameter of the core ranges from 1 7/8 inch for the small rig to 4 - 7½ inches for the large rig. Length of the core sections vary from 10 to 60 feet. Air is usually preferred as the coring fluid, but water and/or drilling mud is also used.

Most environmental impacts of core drilling are of a temporary nature. After drilling and before they are plugged and abandoned, these wells, however, could provide communication between various aquifers. Scraping of access roads to the location and leveling of the site involve removal of surface vegetation, mainly sagebrush. Following completion of the drilling operations, the land surface is restored according to the stipulations set forth in the special land use permit issued by the Bureau of Land Management for operations on public lands. The stipulations specify among other things that, "The grantee will effect a minimum of vegetative or soil disturbances consistent with practical construction operations and will smooth all disturbed areas to conform as near as practical with the adjacent terrain, provide adequate water drainage for any roads constructed to minimize erosion. . . ."

Another stipulation provides that, "All disturbed areas must be returned as nearly as practicable to their original condition or to a condition to be agreed upon by the permittee, the Mining Supervisor, and the District Manager as to the satisfactory standards for such reclamation. This includes, but shall not be limited to removal, storage, and replacement of top soil, and the establishment of vegetal cover. Species will be determined by the District Manager. Reclamation and shall be accomplished as soon as possible." Though the area is seeded after the core-drilling operations are completed, some impacts on the area cannot be totally erased. For example, construction of roads and use of them by heavy equipment produce some soil compaction; in some areas, surface grades are changed that can have an effect on drainage patterns; some vegetation is removed that requires many years to replace (e.g. sagebrush, small trees, and small bushes); and new patterns of erosion may be established by the alteration of the land surface.

2. Land Impact of the Oil Shale Development

The degree to which the development of the oil shale resources on any given tract in any of the three States affect the land on and adjacent to that tract is a function of the location of the tract, the size, type, and combination of the processing technologies involved, and the duration of operations on the lease. A production level of 50,000 barrels per day is the "unit" tract from which subsequent calculations have been made. The land requirements for this level of operation are shown in Table III-3 for various modes of mining, processing, and processed shale disposal. The amount of land surface disturbed would be a function of the total duration of operations on a given lease.

Table III-3. Land Requirements for Oil Shale Processing

Function	
Mining and Waste Disposal	**Land Required, Acres**
Surface Mine 1/ 2/ (100,000 bbl/day)	
Mine Development	30 to 85 per year
Permanent Disposal, overburden	1,000 (total)
Temporary Storage; low grade shale	100 to 200 (total)
Permanent Disposal; processed shale	140 to 150 per year
Surface Facilities 3/	200 (total)
Off-site Requirements 5/	180 to 600 (total)
Underground Mine 2/ (50,000 bbl/day)	
Mine Development (Surface facilities)	10 (total)
Permanent Disposal	
All processed shale on surface	70 to 75 per year
60 pct. return of processed shale underground	28 to 30 per year
Surface Facilities 3/	140 (total)
Off-site requirements	180 to 225 (total)
In situ Processing (50,000 bbl/day)	
Surface Facilities 3/	50 (total)
Active Well area and restoration area 4/	110 to 900
Off-site requirements	180 to 600 (total)

1/ Area required is dependent upon the thicknesses of the over-burden and oil shale at the site. Acres shown are for a Piceance Creek Basin site, with 550 ft. of overburden and 450 ft. of 30 gallon/ton shale (approx. 900,000 bbl/acre).

2/ Assumes 30 gallons per ton oil shale and a disposal height of 250 feet.

3/ Facilities include shale crushing, storage and retorting (excluded for in-situ processing), oil upgrading and storage, and related parking, office, and shop facilities.

4/ See Vol. III Figure (III-11) for conceptual view of surface utilization.

5/ Includes access roads, power and transmission facilities, water lines, natural gas and oil pipelines; actual requirements depend on site location. A 60-foot right-of-way for roads requires a surface area of about 8 acres per mile. Utility and pipeline corridors 20 ft. in width require 2.4 acres per mile.

The overall magnitude of the land impact is given in the analysis below for a basic 20-year period with a possible extension of the activities to a 30-year period. On most tracts this period would include an initial five years of pre-production activity, followed by 15 to 25 years of actual, full-scale production.

a. Surface Mining Land Impacts

Where surface mining could be used, it would have the greatest initial disturbance of land surfaces (and topography), soils, and vegetation. The land surface disturbed in developing the open pit mine itself, for a 100,000 barrels/day operation in Colorado (Table III-1), would directly involve from 30 to 85 acres per year, or 1,100 acres over 20 years of continuous operation. During the early years of an open-pit development, permanent overburden disposal would be off-site. After 16 years, it would be possible to begin disposing of overburden and spent shale in the pit.

Mining of 30 gallon/ton oil shale at a 100,000 bbl/day open-pit operation (Colorado) would require off-site disposal of up to 250 million cubic yards of overburden before pit return could begin. The land area affected would be about 1,000 acres. By carefully selecting the disposal site and applying contouring techniques to control surface drainage, revegetation could begin in the early years and restoration of the disposal area would be possible.

During full-scale operations, 74,000 tons per day of processed spent shale would be produced at a typical plant. At full capacity, such a plant would disturb about 70-75 acres per year, if a dry canyon in the shale area were filled to a depth of 250 ft.

During any open-pit mining operation, the topography would be altered and the environment would be disturbed. The actual area affected would be determined by the thickness of the overburden and oil shale, the mining plan, and the rate of development and restoration.

The development of a surface mine has been detailed in Volume III, Chapter III for a location in Colorado (2). The results of that analysis are shown in figure III-1 for a 30-year development period; total land required for all activities (including processing facilities) is a maximum of 6,650 acres at the end of 30 years. Restoration is assumed to proceed as soon as the ultimate height of the waste disposal pile had been reached for a specific canyon. Three years thereafter, the area is assumed to have been revegetated.[1/] These data indicate that the total land not usable is similar for an operation that uses all surface disposal (3,400 acres) as compared to one that uses backfilling (2,675 acres). However, the impact on the land is different. If surface disposal were used, 6 typical canyons would be affected. For backfilling operations, one typical canyon would suffice. Details of these possible options are given in Volume III.

b. Underground Mining Land Impacts

Room and pillar underground mining would probably be the method most commonly employed for the initial development of oil shale. This

1/ Revegetation success in covering large areas to retard erosion and provide forage for wildlife and cattle over sustained periods of time looks promising, but awaits completion of ongoing research. Reestablishment of climax forest type vegetation is not likely except over long time periods.

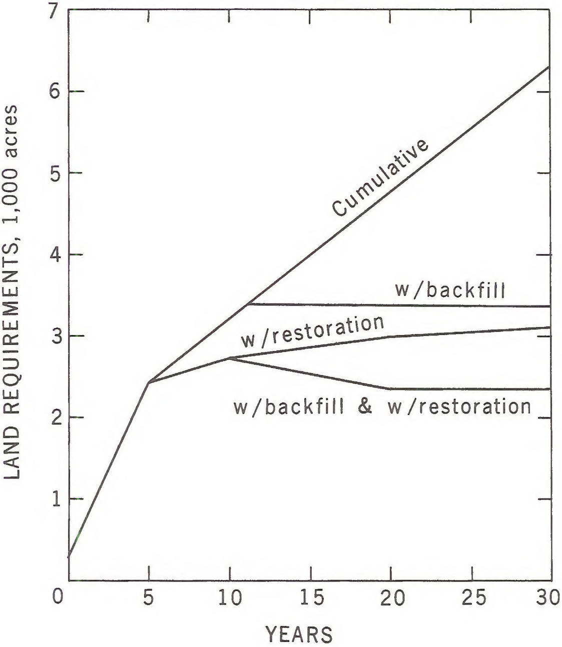


Figure III-1 100,000 Barrel Per Day Surface Mine and Disposal type of mining, with most operations underground, would disturb only about 10 acres of surface land. However, the surface involved in the disposal of the processed shale produced by retorting must also be considered. Two methods are feasible for waste shale disposal: (1) total surface disposal, or (2) a combination of surface disposal and return of the waste to the underground voids left by mining.

Total surface disposal would disturb from 70 to 75 acres per year, or about 1,500 acres over a 20-year period of continuous operation. This acreage could be reduced by the return of the waste material to the mine. Processed spent shale occupies a greater volume than the original rock in place; therefore, only part of the waste could be returned to the mine. With compaction of the waste it is estimated that 60 to 80 percent could be returned underground. During the operation at any lease site, part of the waste (20-40%) would therefore, need to be disposed above ground. For a 20-year lease period this required surface disposal area would be approximately 450 acres.

Three underground developments (2 in Colorado and 1 in Utah) are detailed in Volume III. (2). Data developed from these studies are depicted in Figure III-2 or for a typical disposal option.

Total area required over a 30-year period, if no material is returned to the mine, is 2,210 acres. With backfill, the area is about 1,100 acres--about the same as that calculated for surface disposal followed by the three-year revegetation cycle. However, as with surface mining, the surface disturbance is greater if the material is not returned underground; the amount of usable land is nearly identical in either case.

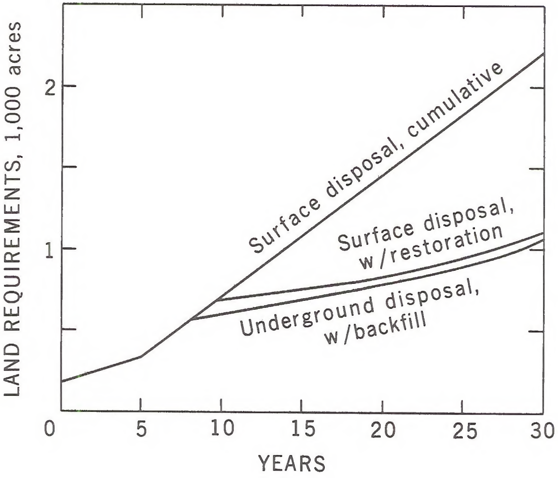


Figure III-2 50,000 Barrel Per Day Underground Mine

c. In situ Processing Land Impacts

In situ processing of oil shale would require about 50 acres of surface for processing facilities. The rate at which land would be disturbed during drilling operations is entirely dependent on the characteristics of the formation to be developed. The range of impact from the prototype case studies (2) is given in Figure III-3.

In situ operations could involve the eventual use of an entire tract over a 30-year period, but the land under development would range from 775 to 1,790 acres at any time after the 10th year. Land impacts would be different from that experienced in the other processing methods and would be similar to those previously described under coring operations. The surface after restoration would be more nearly the same after operations as compared to mining-surface processing.

Although now remote, nuclear methods might some day become a part of the technology. Significant impact examination would have to await such a development before it could be fully described. The impact areas of most consequences, as indicated by current knowledge, would likely include: (1) ground motion, (2) radiation, (3) hydrology, (4) structural response, and (5) economics. Much would depend upon the size of detonation, the location, and the depth. Present judgments of their significance have to be deferred until the potential of this relatively undefined technology can be compared with the choices of the alternatives involved.

d. Facilities and Off-Site Land Impacts

The mined shale is conveyed to a crushing plant and then to a retorting plant, where it is heated to yield shale oil, which must then be upgraded to pipeline quality. The acreage required for a

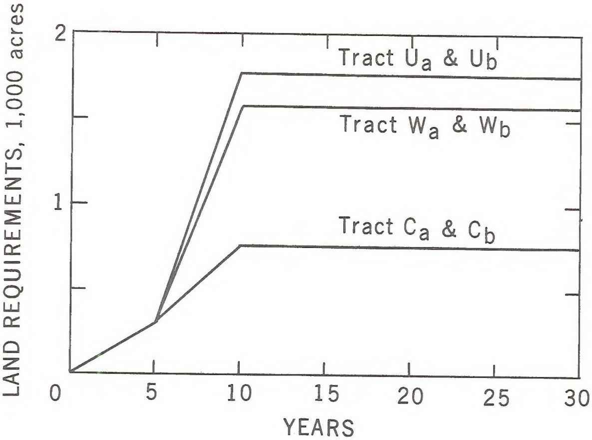


Figure III-3 50,000 Barrel Per Day In-Situ Recovery System modern, well-engineered processing plant is considerably less than is needed for the mining and spent shale disposal operations. A 50,000 barrel per day plant would be expected to occupy and disturb somewhat less than 140 acres for the crushing, crushed shale storage, retorting, oil upgrading, oil storage, and related parking, office and shop facilities. The oil storage area itself would require about 40 acres of this total. For in situ operations, a total of 50 acres would be required for facilities.

Off-site requirements would have an effect on the surrounding surface area to some degree. Access roads, power-and-gas transmission facilities, water lines, and oil pipelines would need to be constructed. Underpasses and suitable fencing may be required to reduce interference with wildlife migration patterns, and with cattle grazing.

It is expected that new power lines would be constructed in accordance with the environmental criteria outlined in Chapter I. Natural gas lines, as required, would be buried underground, using existing techniques for filling excavations, and reseeding of the right-of-way. Water supply lines would be buried, employing similar practices.

Upgraded shale oil from the processing plant sites would be moved to refinery centers via connecting pipelines from the sites to existing transcontinental pipelines. These connecting lines, 12 to 16 inches in diameter, would be constructed so as to ensure minimum surface disturbance, with appropriate revegetation and positive maintenance to prevent leakage. Some isolated and localized leaks may eventually occur, but the probability of a major rupture is remote.

It is not possible to accurately estimate the total off-site surface area disturbed, since this is dependent upon the individual site locations (see Volume III (2)). However, it is expected that an additional 1,700 to 2,000 acres would be needed for each site.

e. Urban Land Requirements

Increased urbanization would be associated with oil shale development as described in subsequent sections of this chapter and be distributed in the three States of Colorado, Utah, and Wyoming, in proportion to the production developed on each of the tracts developed. Because the shale region is now predominantly rural, urbanization would inevitably have an environmental impact on the area, largely removing land from growing use for further home site and community development.

It is difficult to quantitatively estimate the cumulative effects of this urbanization. In general, most new permanent urban construction probably would be in existing population centers at or near the shale lease sites in each State. Temporary employment for plant and urban construction would be substantial (approximately equal to permanent operating employment), creating need for "temporary" housing (mobile home parks, for example) in addition to permanent housing. Expansion of support facilities (business districts, hospitals, schools, and other) would also result along with an accompanying environmental impact on the land. A few new small communities may appear, but are likely to be scattered. It is possible that as much as 10,000 acres of land would be urbanized by 1980 and 15,000 to 20,000 acres by 1985 as a result of oil shale processing activities and the resultant increase in regional population.

f. Cumulative Land Impacts

The foregoing analyses of land impacts have been combined with the projected development schedule of Table III-2 to develop an order-of-magnitude estimate of the cumulative land impact over a period of time. This analysis must necessarily be approximate due to the many assumptions that must be made and the very-long time projection of nearly 40 years. The results, shown in Figure III-4, show that cumulative land undergoing restoration rises more slowly than does cumulative production; the land impact begins to level off at about 20,000 acres. This is due to the assumed restoration schedule and the volume of the canyons used in the analysis. Total cumulative area that would be affected would approximate 50,000 acres with no backfill or about 35,000 acres if backfill were employed.

As the technology advances, an oil shale complex at full-scale production may extract recoverable reserves in greater quantity than anticipated in developing these data for the lease tracts. In this case, time periods of 50 to 70 years may be possible.

Additional land for urban development (15,000 to 20,000 acres) is not included in this analysis nor are the utility right-of-ways that would be needed (probably less than 10,000 acres total).

The canyon areas assumed to be used for disposal operations would be altered in appearance. The canyons to be used for the prototype disposal area have bare slopes largely void of vegetation with sandstone outcrops. Valley bottoms are deeply dissected and contain unconsolidated alluvium fill (clay, silt, sand, and marlstone). Since live water is not found in the prototype disposal areas, the erosion of the valley floors is caused by flash floods common to the area.

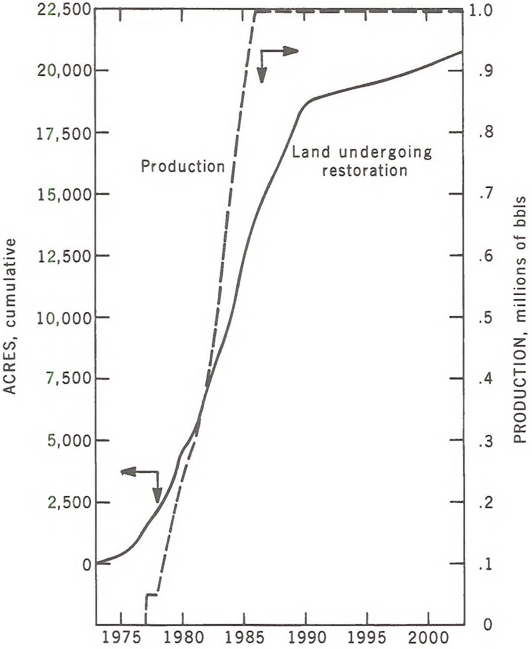


Figure III-4.- Shale Oil Production from Active Areas and Land Undergoing Restoration

Disposal would gradually fill such canyons along their entire length to a level just below the rim. The open end of the canyoun would be gently sloping at an 18° slope and rise to about 250 feet. The top of this disposal area would be sloped to permit natural drainage. Vegetation would be established on the surface of the slope near the open end of the canyon as new materials is added in 1 to 2 feet layers and compacted. Vegetation would be established on the top only after the pile had reached its final height.

Erosion would be controlled during buildup by upstream diversion dams and, perhaps, by canals and culverts to carry runoff water around and/or under the disposal site. Sediment that may erode during the buildup of the pile would be trapped in impermeable ponds near the base of the sloping surface.[1/] Water and sediment would then be recycled and be used in the disposal operations.

The net effect of this operation would be to fill the canyon with well stabilized material which would be revegetated and gently sloped at the top and face. The total sediment load from the canyon may be less than the sediment now contributed by the area.

1/ Approximately 50 to 100 acres assuming a 10 foot reserve depth of retention.

g. Ownership Impacts

Title to Federal lands in the oil shale area has been clouded for years because of the existence of unpatented mining claims. Unpatented mining claims embrace at least 80 percent of the area and were filed for locatable as well as now leasable minerals, including oil shale. Validity determinations of these claims and obtaining relinquishments on claims not legally contested has resulted in resolving and clearing about 30 percent of the post-1920 claims from the area. Limited progress has been made in final adjudication of the pre-1920 claims.

Of the 2.6 million acres of oil shale land, approximately 54 percent is Federally-owned, 40 percent privately-owned, and about 6 percent is owned by the involved States. The impact of oil shale development, which does not involve clouded title under the prototype program, on the lands with clouded title cannot be predicted. However, if development were to be successful for a mature industry then the title to the involved lands with clouded title would have to be resolved.

B. Impact on Water Resources

The water resources of the area are complex and varied as indicated in Chapter II and requirements for an evolving oil shale industry will change with time. This section of the report establishes the relationship between the demand for and supply of water to assess the cumulative impact of a 1 million barrels per day industry.

1. Process Needs

The net water consumed for a "unit" 50,000 barrels per plant is given in Table III-4. At least one-half of the total is used in the disposal operations to prevent dusting and to provide the mechanical properties needed to attain a stable pile (see Chapter I). Since leaching from this pile would be minimal (Chapter I), the water that would be required in disposal operations does not need to be of high quality. Similarly, water required for local dust control in the plant area can be less than potable. This suggests that many sources of water can be used other than that obtained directly from the Colorado River system.

2. Supply Sources

The sources of water are varied as can be seen by referring to the flow diagram in Chapter I, Figure I-10. Water would be available from the retorts, from oil-shale upgrading, and from the mine. The most important source, and the one least subject to quantification with available data, is the water that may be produced during mining operations.

Throughout the oil shale area, but particularly in Colorado, dewatering would be required in most oil shale mining operations. Water occurs above, below, and within the shale beds, and certainly

Table III-4. Typical Water Consumption for a 50,000 Bbl/Day Oil Shale Plant

Assumptions:

(1) Process sequence includes underground mining, surface retorting, processed shale disposal by wetting and compaction, upgrading of shale crude by partial hydrofining.

(2) Process cooling primarily by aerial condensers.

(3) Raw shale - 30 GPT: processed shale wetted with 20% water for compaction.

	Net Water Consumed Cubic Ft/Sec
Mining1/	0.3 - 0.4
Crushing (dust control)1/	0.2 - 0.3
Retorting1/	0.8 - 1.0
Processed Shale Disposal1/	3.4 - 5.82/
Shale Oil Upgrading	2.0 - 2.5
Other (Personnel, construction, etc.)	0.1 - 0.6
Total	6.8 - 10.6

*If slurry disposal were to be used this maximum could be as high as 7.0 cubic feet/sec.

1/ In situ operation would eliminate most of these water requirements.

2/ If slurry disposal were to be used this maximum could be as high as 7.0 cu. ft./sec.

would have to be removed as part of surface and subsurface mine development. Some in situ operations also may require dewatering, but probably in lesser amounts. The quality of the water removed would range from fresh and potable to highly saline as described in section II.

Most of the available water data have been developed for the Piceance Creek Basin of Colorado. The complexity of the movement of water through the features that exist in the Basin has been described by Coffin and others (3) and is summarized as follows:

> "The regional ground-water movement in the northern part of the basin is from the edges of the basin toward the two major drainages of the basin, Piceance and Yellow Creeks. The principal water-transmitting zone is the leached zone. Some data indicate that near the edges of the basin the potentiometric head in the leached zone is lower than the head in the upper zone. Near the center of the basin, data indicate that head in the leached zone is higher than head in the upper zone. These head relations indicate that even though the major direction of flow is toward the center of the basin, there is also vertical flow between zones. Near the edges of the basin, water moves from the upper zone downward through the Mahogany zone into the leached zone... In the center of the basin water moves upward from the leached zone through the Mahogany zone into the upper zone where it is eventually discharged into Piceance or Yellow Creek or is evaporated or transpired."

Thus, the flow of water is both horizontal and vertical through the Basin. Data are not yet available to completely quantify this very complex phenomenon which makes any estimate of water available from mines extremely tenuous. Estimates of the transmissivity of the water bearing zones have been made for most of the sites nominated in Colorado under the proposed prototype leasing program. As shown in Table III-5, the amount of the water varies widely between the upper (Mahogany) zone and the lower zone and depends on site location.

3. Process Water Trial Balance

This section provides on order-of-magnitude estimate of the water that may enter and leave a surface processing complex that uses either an underground or surface mine. Two hypothetical mines in Colorado are used in the analysis; the location and characteristics of which are given in Volume III. A number of assumptions are needed to develop the data presented in these figures, the key assumption being the amount of water thay may enter a mine over time. Although the data used to develop these "model" mines are the best currently available, hydrologic tests now in progress by the U. S. Geological Survey would improve produced water estimates. Additional geological and hydrological drilling and testing would be required to provide design data for a mine however, only with actual development can these analyses be confirmed.

Underground Mine. In the hypothetical underground mine (Figure III-5), produced water would vary with time (see part (a), Figure III-5). An estimated peak volume of 20 cu. ft/sec. (12.9 million gallons of water/day) could be pumped from the mine when it has reached a radius of 1 mile (3). This amount theoretically decreases rapidly to about 5 cu. ft/sec. at the end of 25 year of development.

Table III-5 -Aquifer Transmissivity of Nominated Oil Shale Tracts in Colorado. 1/

Site No.		Upper Zone Transmissivity gpd/ft.	Lower Zone Transmissivity gpd/ft.
Colo.			
1		2,000 - 5,000	2,000 - 5,000
2		* 2/	* 2/
3		* 2/	* 2/
4,5,7,8 (C-a) 17		1,000 - 2,000	10,000 - 15,000
6		1,000 - 2,000	0 - 1,000
9		* 2/	* 2/
10		10,000 - 15,000	10,000 - 15,000
11		10,000 - 15,000	10,000 - 15,000
12		1,000 - 2,000	1,000 - 2,000
13	(C-b)	5,000 - 10,000	2,000 - 5,000
14		* 2/	* 2/
15		* 2/	* 2/
16		2,000 - 5,000	0 - 1,000

1/ Source: Reference (2)

2/ No Data

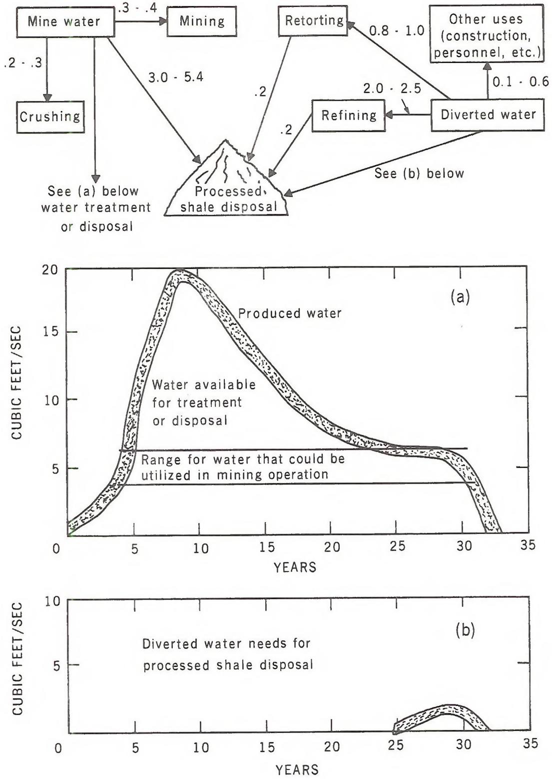


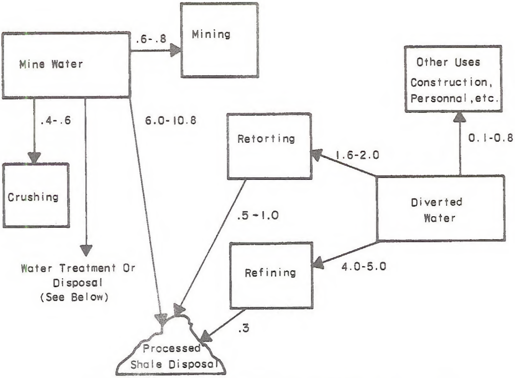
Figure III-5.-Water Supply and Demand in cu ft/sec for Underground Mine, 50,000 Bbl/Day of Shale Oil

Other water from the retorting and refining operations would be available for processed shale disposal in the quantities shown in the figure.

In the early stages of mine development, some of the water may be of high quality and therefore could be used in those procedures which require low salinity water.

Because of the eventual depth of the mine and the probable high salinity of waters produced at that time, untreated water from mines could probably not be used in either retorting or refining or for "other" uses. Water diverted from the Colorado River system would therefore be required for these uses. However, for the major water requirements, processed shale disposal, surface water may not be required over the first 25 years of the operation as indicated in figure III-5, part (b). A complete trial water balance for this mine is presented in a subsequent part of this section.

Surface mine. This hypothetical mine is also in Colorado and is scaled to 100,000 barrels per day of shale oil production. Water supply and demand for this plant is given in figure III-6. The water produced during mining would depend upon the depth and rate of advance of the pit floor (see figure III-7) as well as the aquifer characteristics. To keep the floor of the pit dry, the water table in the vicinity of the mine must be lowered at a rate as fast or faster than the rate of pit development. A series of wells could be used to lower the water



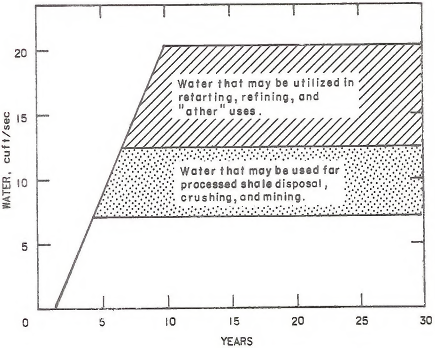


Figure III 6.- WATER SUPPLY AND DEMAND cuft/sec FOR SURFACE MINE 100,000 bbl/day

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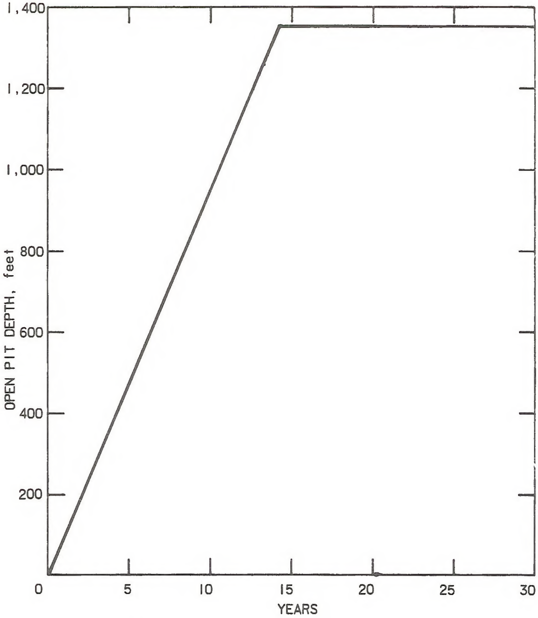

Figure-7.—Pit Depth Advancement for 100,000 bbl/day Surface Mine table and in so doing, a ground-water supply would be developed which might have very low salinity.

Water produced in the above operations could be used to supply the water requirements for crushing, mining, and processed shale disposal. Depending on the salinity, the produced water may also be suitable for retorting and refining and, possibly, for supplying the drinking water and sanitation needs of the plant. If the amount of water pumped is greater than these combined needs, the excess water could be treated or disposed of by injection or evaporation. If suitable in quality, it may be released to augment the flow of surface water in the area.

In Figure III-6, the curve indicates the possible distribution of the water produced from this hypothetical surface mine. The middle dotted area represents the range of water requirements for mining, crushing, and processed shale disposal. The upper (striped) area of the curve represents the range of water that may be utilized for retorting, refining and "other".

Trial Water Balance. - The amount of water available from dewatering a mine depends on the aquifer characteristics and the quality of the water, which determines its suitability for various processes.

Data are not available to determine the precise quantity and quality of water that would be pumped from either a surface or underground mine. However, it is useful for planning purposes to calculate a trial water balance for hypothetical mines based on reasonable assumptions (Table III -6).

Table III-6 - Trial Water Balance for Two Hypothetical Mine Developments in Colorado (2).

	New Water, Acre Feet per Year	
	Underground Mine 1/	Surface Mine 2/
Water Required for:		
Crushing	150- 220	300- 440
Mining	220- 290	440- 580
Processed shale disposal	2,480-4,230	4,960- 8,460
Retorting	580- 730	1,160- 1,460
Refining	1,460-1,820	2,920- 3,640
Other uses 3/	70- 440	80- 580
TOTAL	4,960-7,730	9,860-15,160
Water Available from:		
Retorting	170- 360	340- 730
Refining	110	220
Mine development 4/	7,880	12,410
Other 5/	100	200
TOTAL	8,260-8,450	13,170-13,560
Water Balance		
High quality water requirements 6/	2,110-2,990	4,160- 5,680
High quality water from mine 7/	3,960	6,205
EXCESS HIGH QUALITY	1,830- 950	2,045- 525
Poor quality water requirements 8/	2,850-4,740	5,700- 9,480
Poor quality water from mine and processing 9/	4,320-4,510	6,965- 7,365
EXCESS POOR QUALITY	1,660-(-)420	1,665-(-)2,515
Trial Water Balance:		
Excess high quality	1,830- 950	2,045- 525
Excess poor quality	1,660-(-)420	1,665-(-)2,515
SURPLUS 10/ or DIVERSION (-) 11/	3,490- 530	3,700-(-)1,990

1/ 50,000 barrels per day
2/ 100,000 barrels per day
3/ Primarily net domestic consumption for associated population
4/ Average produced water over 30-year period (3)
5/ Other sources, such as boiler blowdown, bleed-off from cooling water, etc.
6/ Requirement for retorting, refining, and other uses such as drinking and sanitation purposes.
7/ Assumes half of the produced water from the mine is of high quality
8/ Requirement for crushing, mining, and spent shale disposal
9/ Processes include retorting and refining
10/ Surplus poor quality water would require desalting, evaporation in impermeable ponds, or disposal by subsurface injection
11/ Diverted water would be from surface water in the Colorado River system.

In this example, the water required and the water available has been previously given in figures III-5 and III-6. Those data have been converted from cubic feet per second to acre feet per year to facilitate the discussion. In this example, half of the mine water was assumed to be high quality (low salinity) water and the other half poor quality (high salinity).

In the water balance, the needs for those functions that require high quality water have been balanced against the available amount of such waters. In this case, it is assumed that 50 percent of the pumped mine water can be used. The remaining mine water and the water provided from retorting and refining is balanced against those water needs that would not require high quality water, such as processed shale disposal.

The tract water balance given near the bottom of table III - 6 is a balance between the excess high and the excess poor quality water.

The hypothetical underground mine in the example would have excess water to its needs; from 530 to 1830 acre-feet per year good quality water would be available for off-site uses or for discharge to the drainage system, or from zero to as much as 1,660 acre-feet per year. of poor quality water would require desalting, evaporation, injection or some other method of disposal. The surface mine might have a surplus of both good water and poor water or, the mine could consume all of the water pumped and require as much as 1990 acre-feet per year of surface water to be diverted from the Colorado River System and transported to the mine.

Some of the excess water may also be used to supply the water that may be needed in revegetation of the processed shale disposal areas. These requirements have not been factored into the analysis above, however, assuming that the new surface area of a typical canyon used for the disposal area is 800 acres and that water is to be applied at the rate of 1 foot per year, a total of 800 acre-feet of water is needed. This amount might be available as surplus as indicated in the trial water balance.

The full range of possibilities for this example is given in table III - 7 . The data in the "50 percent" column is the same as that presented in table III -6 . Derivation of the data in the remaining colums followed the format ot table III-6. Examination of the "surplus or diversion" row shows the extremely wide range of possible results.

Table III-7 - Water Balance as a Function of Pumped Mine Water Quality, acre-feet/year 1/

	Underground Mine			Surface Mine		
High quality mine water, percent of total	0	50	100	0	50	100
Excess water of poor quality	3,520 to 5,600	(-) 420 to 1,660	0	3,690 to 7,860	(-)2,515 to 1,655	0
Excess Water of high quality	0	950 to 1,830	530 to 3,490	0	525 to 2,045	3,700 to (-)1,900
Surplus or Diversion (-)	5,600 to (-)2,990	530 to 3,490	530 to 3,490	7,860 to (-)5,680	3,700 to (-)1,990	3,700 to (-)1,990

1/ See table III - 6 for derivation of 50 percent columns

4. Impact on Water Quality

The depletion of the Colorado River system that would be associated with an oil shale industry of 1 million barrels per day, would cause a slow increase in the salinity concentration of the Colorado River at Hoover Dam. This would happen because the comparatively low mineral content water that would be diverted would no longer be available to dilute the higher mineral content water that enters the Colorado River downstream from the oil shale region.

If the maximum amount of water required for a 1-million barrel per day industry is obtained from the river (see table III-8)[1/] the salinity at Hoover Dam would be expected to increase between 6 and 10 mg/l. According to Bureau of Reclamation records, the current (1971) salinity is about 730 mg/l. Thus, consumptive use of water for oil shale development could increase the salinity by 1.4 percent.[2/] In addition, small, but yet unquantifiable, effects on salinity could result from ground-water depletion, and from accidental releases of poor quality water. Further increases in the salinity attributable to diversion for oil shale would not be expected after 1985 if the output of the industry is held at 1 million bbls/day. Substantial amounts of water may be available from mine development (discussed above) reducing the requirements for Colorado River system water.

Depending upon location conditions, mine dewatering can have extensive effect on aquifers and streamflow. Decreasing the water levels or artesian pressures of aquifers could dry up some springs

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1/ A 1 million barrel per day industry would require from about 79,000 to 124,000 acre-feet of water annually, a substantial portion of which may be available from mine dewatering.

2/ Underground mining/surface processing would result in the maximum water consumption. If this method were used to develop a 1-million barrel per day industry, consumptive water use would range from 105,000 to 156,000 acre-feet per year and the salinity at Hoover Dam would increase by 8 to 12 mg/l; a 1.6% rise.

Table III- 8 Water Consumed for Various Rates of Shale Oil Production [1/]

Function	Shale Oil Production - barrels per day			
	Net Water Consumed, acre feet per year			
	50,000	100,000	250,000	1,000,000
Mining	220 - 290	440 - 580	1,100 - 2,900	3,500 - 6,100
Crushing (dust control)	150 - 220	300 - 440	800 - 1,100	2,400 - 3,500
Retorting	580 - 730	1,160 - 1,460	2,900 - 3,700	9,300 - 11,700
Processed Shale Disposal	2,480 - 4,230	4,960 - 8,460	12,400 - 21,200	39,700 - 67,700
Shale Oil Upgrading	1,460 - 1,820	2,920 - 3,640	7,300 - 9,100	23,400 - 29,100
Other [2/]	70 - 440	80 - 580	400 - 2,300	1,000 - 6,300
Total	4,960 - 7,730	9,860 - 15,160	24,900 - 40,300	79,300 - 124,400

1/ Assumes the same technologies as those used to develop Table III-2.
2/ Primarily net domestic consumption for associated population. Source: Reference (4)

and intercept inflow to and divert water from the streams. Some interference with surface stream flow and existing water rights can be expected. The dissolved solids content of ground water in the principal aquifer (the Parachute Creek Member of the Green River Formation) in the White River part of the Piceance Creek Basin, illustrates the effects of regional ground-water flow through rocks containing highly soluble minerals. As stated earlier, water from precipitation enters the ground-water system and moves toward Piceance and Yellow Creeks in the topographically low part of the Basin, (Figure III-8). Ground water in the recharge area is fresh or slightly saline and contains less than 3,000 mg/l of dissolved solids. Ground water that is discharged from the Parachute Creek Member to the surface in the lower Piceance and Yellow Creeks contains several thousand mg/l of dissolved solids, mostly sodium bicarbonate leached from the nahcolite that occurs in the Parachute Creek Member.

Based upon hydrologic data from a limited number of wells, mines or wells tapping the leached zone (figure III-8) would probably produce several thousand acre feet of water per year for many years. Substantial declines in water levels would accompany such withdrawals, possibly resulting in the drying up of springs in areas where the leached zone is a source of such water, and possibly resulting in the compaction of the leached zone with an accompanying subsidence of the land surface. Extensive aquifer dewatering could cause movement of the fresh water-salt water interface, contaminating aquifers that now are comparatively fresh or freshening aquifers that are now salty, depending on the point of withdrawal. The magnitude of these impacts

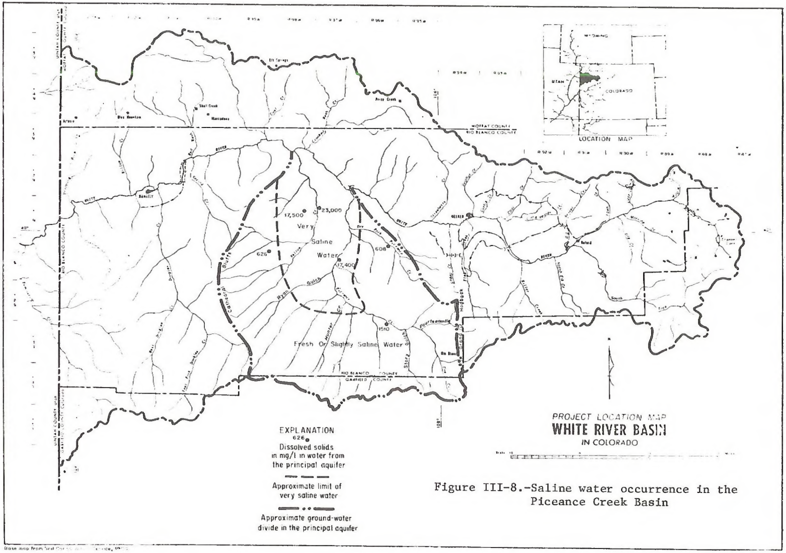

Figure III-8.-Saline water occurrence in the Piceance Creek Basin can only be assessed through actual development.

Water produced in excess of what may be needed must be properly handled. If it is of good chemical quality, naturally or following treatment, it is expected that the water would be used for nearby applications or discharged to streams for downstream use. Discharging excess water into dry or nearly dry channels will cause stream channel erosion due to increasing the low flow of the streams, unless the water is carried to the point where it can be discharged into a sizeable stream.

Excess water of poor quality would present a disposal problem. Desalination is possible with the remaining high quality water being used on other leases or returned to surface streams. More probably, however, it would be injected into compatible subsurface aquifers or evaporated in impervious impoundments. Injection of fluids under high pressures in other areas have caused earth tremors. The magnitude of the potential problems associated with the disposal of excess waters will depend entirely on local conditions. Data needed to evaluate the problems would be obtained before development begins.

Mineral leaching by water percolating through the waste piles would not be anticipated to be a significant problem, since moistened and compacted, retorted shale has exhibited low permeability to water in experimental tests (see Chapter I). Natural cementation takes place over a relatively short time period if the spent shale has been moistened and compacted, tending to minimize surface leaching and sediment run-off (see Chapter I). No tests, however, have been conducted on large volumes of materials, such as would be continually deposited during routine operations, since it is extremely difficult to simulate field conditions on a small scale. It might be expected, however, that natural erosion of spent shale piles would occur with time.

Spent shale disposed of in underground mines could be subject to leaching if the mine workings were flooded while active or after mining operations ceased. If this occurred, some minerals might be leached and find their way into aquifers. However, mineral concentrations decreases rapidly with continued percolation as discussed in Chapter I. Data are not available to quantify either short or long run impacts.

Accidental spillage could come from rupture of pipelines and failure of storage tanks. However, the average oil that may be lost from pipelines is insignificant and that from ruptured tanks can be safely contained in dikes as described in Chapter I.

Water in the oil shale areas would receive the effluent from the domestic waste from an increased population of 47,000 people by 1981 (see Section G below). Wastes would be generated over a large area, but a large proportion would be concentrated in a few communities. A wide range of waste-treatment methods would be employed, ranging from septic tanks to highly effective municipal treatment, and the net increase in organic and nutrient loading of surface and ground water would be dependent on the kind and quality of treatment the waste receives. Problems such as algal blooms or oxygen deficiency could occur in areas of concentrated population, unless adequate sewage treatment facilities were constructed to keep up with population growth. The long term effect of industrialization in the region could lead to some cumulative decline in water quality.

Depending upon underground conditions, ground-water contamination could occur during in situ extraction. Organic materials formed during retorting could escape into aquifers if pressure conditions were unfavorable. Water analyses from monitoring wells would be needed to detect any such impending contamination, and the retorted area could be drained to prevent the flow of contaminated water to the surrounding area. Water drained in this manner would then be treated to remove the contaminants and make is usable on site or suitable for disposal in streams. However, if dewatering is done, some inevitable damage would result, as discussed under other methods of mining.

C. Impact on Air Quality

The principal sources of potential air pollution from oil shale development would be dust and vehicular emission during construction, solid particulates resulting from mining and spent shale disposal operations, dust produced during crushing and retorting operations, and burning of gases from retorting and refining operations, for example, in firing various furnaces in the refinery or in generating steam, and the like. These are considered separately below.

1. Construction

During construction, operation of mechanical equipment would result in exhaust emissions from diesel and gasoline engines, noise, and dust. Noise would, in general, be more noticeable than similar highway construction activities because of the lower ambient sound level. Emissions and dust are controllable to accepted standards, the former by mechanical means, the latter by water spraying, watering down, etc. These effects would be only on a short-term nature of under about 2 years.

2. Dust and Particulates

Particulate matter and dust will be significant only in mine development. Particulates are controllable by settling chambers in combination with water sprays. Ventilation air at about 2 to 3 million cubic feet per minute would contain about 20 pounds of dust per hour, except during blasting operations (probably three times per day) when levels of 60 pounds per hour may be reached. This material would be controlled by water sprays and disposed of in the disposal area.

Enclosed crushing and screening operations and conventional technology (wet scrubbing, bag filters, and/or dust suppression with water) are adequate to reduce emissions to below about 35 pounds per hour in 400,000 cubic feet per minute of air (0.01 grains/cu. ft.). By comparison the EPA standard for incinerators--the only comparable standard available--is 0.08 grains per cu. ft.

Conveying operations offer potential for dust emissions due to wind, spillage, or process upsets. Enclosed conveyors and dust collectors at transfer points will eliminate this potential problem. Some spillage may still be expected, and it would be necessary to provide for reclaiming such spillage.

Diesel exhaust emissions contain nitrogen oxides, carbon monoxide, aldehydes, and hydrocarbons. These may need to be controlled using various catalytic and exhaust recycle methods. As part of a comprehensive program on mine health and safety, the Bureau of Mines is conducting extensive research on the safe use of diesels underground. The results of this work will be available to guide the use of this equipment in any future commercial oil shale operation.

3. Stack Gases

As explained in Chapter I, treatment to recover the maximum amount of oil would also remove water and particulate matter. If retort gases were used in subsequent operations, sulfur oxides would be emitted in proportion to the sulfur content of the gases. For example, the retort gases shown in Chapter I, Table I-3 may be burned in gas turbines for power generation. Depending on the operating mode for an internal combustion process, the equivalent sulfur in the stack gas would be between 0.9 and 1.1 lb of sulfur per million Btu fired in the turbines.1/ For the indirectly-heated process, sulfur in the flue gas would be about 5 lbs per million Btu.2/ (See Chapter I, Table I-3 for gas composition). Most in situ gases probably would be too low in heating value for beneficial use but would be efficiently burned as a means of of disposal (See Chapter I, Table I-9). Sulfur release would approximate 2.8 pounds per million Btu.3/

The sulfur levels above exceed the Environmental Protection Agency (EPA) standard for stationary sources, which is 0.6 lb per million Btu. Very probably, the sulfur content of the retort gases can be adequately reduced using the sulfur recovery facilities available as an integral part of the oil upgrading plant. In any case, technologies are available to reduce the H_2S concentration in the retort gases before combustion to a level that would result in acceptable sulfur emissions. Examples of processes for this purpose include iron oxide boxes (5) and wet scrubbers employing hot potassium carbonate or amines (6). Sulfur dioxide may also be removed by stack gas clean up devices which should be available in the foreseeable future. A potential "scrubbing" compound is the nahcolite produced with oil shale. If other fuels are required in the plant, they would be essentially free of sulfur, being either supplemental natural gas or low-sulfur oil.

Nitrogen oxides (NO_x) are formed during the combustion of all fuels, as a result of the "fixation" of nitrogen from the combustion

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1/ Assumes 583 million standard cubic feet of gas per day.
2/ Assumes 46 million standard cubic feet of gas per day.
3/ Assumes 1,458 million standard cubic feet per day.

air. Additional NO_x may also be formed from chemically bound nitrogen in liquid or solid fuels. The chemistry of NO_x formation is still somewhat incompletely understood, and the technology for NO_x reduction is still developing. For stationary boilers, it has been demonstrated that changes in burner design, flue-gas recirculation, and operating with low excess air, alone or in combination, effectively reduce NO_x emissions below the EPA standard, which is 0.2 lb NO_2[1/] per million Btu. Regarding gas turbines, NO_x in the exhaust gases has been reduced to an acceptable level by steam injection in the combustor, which is believed to lower the mean flame temperature.

Hydrocarbons and carbon monoxide may also be released in small quantities (7).

4. Sulfur Recovery Unit

If it is assumed that the conventional Claus process would be used to recover sulfur from the refinery gases, sulfur in the process tail gas would correspond to a daily emission of about 4.5 tons of equivalent sulfur. Standards of the State of Colorado limit such emissions to 5 tons daily. Although the calculated value is less than the Colorado standard, it would seem advisable to add a tail gas sulfur recovery unit, such as now are being put into use in the industry, to reduce the sulfur effluent. Approximately a 90 percent reduction is reasonable to expect. Alternatively, the Stretford process, which is receiving considerable attention in this country as a substitute to the Claus process for refinery operations, would also be expected to

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1/ Emissions consist mainly of NO, which oxidizes to NO_2 in the atmosphere. Consequently, the NO is calculated to NO_2 and added to the small amount of NO_2 formed simultaneously with NO during the combustion process.

reduce the tail gas sulfur to about 10 percent of the amount noted above. (8)

5. Cumulative Impact on Air Quality

The potential air pollution problems accompanying oil shale development are similar to those already encountered elsewhere in industry. As a result, the techniques now in general industrial use or under development to control the particulates, sulfur oxides, and nitrogen oxides present in various flue gases, or as dusts produced in mining, crushing, and mineral waste disposal, would be applicable to oil shale processing.

The amounts of "fugitive" dust from mining, crushing, and conveying large tonnages of both raw shale and spent shale which are not collected by the standard capture techniques previously mentioned, are difficult to quantify. At each of the projected eleven plant sites comprising a one million barrel per day industry, assuming 98 percent primary dust capture efficiency, there could be up to 40 tons of "fugitive" dust per day. This is a manageable quantity,[1/] much of which would probably be controlled by proper plant practice with respect to cleanliness (water hosing, water sprays, etc.).

It is expected that residual dust from the processed shale disposal operations would be adequately controlled by wetting and compaction. The subsequent cementation reactions which result throughout the shale disposal piles, including the surface, could be expected to virtually

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1/ In contrast to particulates in powerplant stack gases, which are emitted up to several hundred feet in the atmosphere, the fugitive dust from oil shale processing will tend to collect and settle to earth in the vicinity of the plant itself.

eliminate fugitive dust release from the disposal operations.

Product gases from retorting and refining operations would be nearly free of particulates by virtue of the recovery procedures used in separating them from the oil and other liquids with which they are co-produced. These gases could not be released directly to the air; instead they would be treated for sulfur reduction, if warranted, and then introduced into the plant fuel supply system to be burned to satisfy process and utility system heat requirements. Thus, such materials as carbon monoxide and hydrocarbons present in the gas originally produced (and that would pose air pollution problems if released to the atmosphere) would be efficiently burned.

Although catalytic conversion processes will probably be involved in upgrading shale oil on site, they are expected to be fixed-bed hydrogenation systems with little, if any, of the emission-release problems characteristic of the moving or fluid-bed systems that historically have released catalyst and other particulates to the air. Some small amount of sulfur dioxide will be inevitably released, however, in the tail gas from the sulfur recovery facilities. As discussed earlier in this chapter, this sulfur source can be readily controlled to low limits (of the order of only 10 tons per day from the entire one million barrels per day industry).

Residual concentrations will remain of sulfur and nitrogen dioxide which will be released to the atmosphere. To estimate these concentrations, it has been assumed that: (1) Minimum standards for these pollutants will be attained and (2) development will occur according to the schedule described in table III-2. Cumulative loading to the atmosphere from all sources [1/] would increase gradually to a maximum in the ranges of 230 to 340 tons per day of sulfur and 80 to 120 tons per day of nitrogen dioxide. These levels would be maintained as long as the industry output continues at the 1 million barrels per day level of production.

The impact of this cumulative loading on ambient air quality cannot be determined with available data, but will tend to reduce the average annual visibility. Temperature inversions and air currents are typical of the Colorado River Valley and plants that may be located so as to contribute to the effluents in this Valley could aggravate the effects on the public.

The following description is given of temperature inversions in Colorado (9):

> "A night-time inversion, with light drainage winds, is typical throughout the Piceance Basin. Under these conditions the typical night-time surface flow pattern is down the creek drainage to the north and northeast, then turning westward down the White River valley. The vertical temperature structure is usually neutral to moderately unstable during afternoon, with a temperature inversion forming shortly after sundown. The trapping layer under this inversion is probably less than 1,500 feet thick. A short-term temperature record on Cathedral Bluffs indicated that the inversion height is usually below 8,500 ft. (mean sea level)." (Surface elevations range from 6,600 to 7,400 ft. on Tract C-a, and from 6,400 to 7,100 ft. on Tract C-b).
>
> "During mid-winter, the inversion normally breaks at least by early afternoon. Under certain synoptic conditions, however, temperature inversion conditions may persist for several days at a time. During the summer and fall months, the inversions will normally break by mid-morning."

1/ Not included is the minor amounts of pollutants that would be released from approximately 900 vehicles per day that would transport about 1,800 workers to each site. Based on Environmental Protection Agency standards for 1973 (carbon monoxide (CO) = 39 gm/mile, hydrocarbons (HC) = 3.4 gm/mile, and oxides of nitrogen (NO_x) = 3.1 gm/mile) and a round trip distance of 120 miles, the residual concentrations of these pollutants would be as follows: (in tons per day): CO = 4.7, HC = 0.4, and NO_x = 0.4.

It is clear from the above that source emissions to the atmosphere must be so controlled that pollutants would not accumulate under inversion conditions. Wherever feasible, processing facilities should be located on upland surfaces rather than in valleys and canyons.

In Utah the range of surface elevations on each of the sites nominated under the proposed prototype program (2) is only approximately 1,000 ft. (4,900 to 5,900 feet). Offsetting this is the fact that these sites have the lowest mean elevations of all the sites and the prevailing winds are from the southwest on both proposed tracts. Any uncontrolled pollutants would therefore tend to affect the Rangely, Colorado, population center.

The situation in Wyoming is different from the other two state areas, with regard to meteorological dispersion of air pollutants. Most of the time, predominantly westerly winds sweeping across the Kinney rim would be expected to fan stack plumes out in the prevailing wind direction. Although meteorological data are needed to adequately describe mixing depths and the degree of dispersion, inversion conditions would be expected to present less of a problem in Wyoming than in Colorado.

The long-term effect of industrialization in the region would result in a decline in general air quality.

D. Impact on Fish and Wildlife

1. Impacts of Oil Shale Operations

a. Access

The opening of roads and trails into relatively undisturbed areas would result in a combination of new pressures on localized fish and wildlife populations. Opening of tracts would be accompanied by improved highways and in many cases hunting pressures and other human uses would be locally increased in tract vicinities. One of the most significiant fish and wildlife tradeoffs of a regional oil shale industry would be the widespread loss of remote-terrain hunting qualities, caused by visual and audio impacts of roads, pipelines, transmission lines, signs, air traffic, etc.

b. Disturbing Factors

Human activities and associated noise accompanying construction and operation (road, oil pipeline, and powerline construction; vehicle traffic, etc.) of an oil shale installation would result in a net effect of stress and disturbance to normal wildlife behavior and activity patterns. Most species would by nature avoid such areas during periods of disturbance. Depending upon lease site characteristics, species which would be most affected by such disturbances include mountain lion, bear, elk, mule deer, antelope, bob cats, sage grouse, eagles, hawk, and various species of migratory birds.

However, some species, such as mountain lion, elk, peregrine and prairie falcon, would be intolerant and the areas would largely be lost to them as suitable habitat.

If an air strip were constructed in conjunction with an oil shale operation, the resulting air traffic would result in some additional aerial disturbance of mule deer and other big game, and wild horses. Species such as elk and mule deer are particularly vulnerable to stress induced from routine low level flights and aerial harassment. The extent of such aerial disturbance would be dependent upon the number and location of air strips and the volume of air traffic which would be involved.

Although the impact of each particular disturbance in itself would be relatively small, the net effect over the life of each particular lease would be a chronic disturbance and displacement of wildlife in the tract vicinity.

c. Loss of Habitat

Where oil shale operations would require physical use of undeveloped lands for mining, pipeline and road construction, buildings, etc., the existing values of those lands for wildlife food and cover would be generally lost. Accurate land use data which would be required for a full scale regional oil shale industry is not available, but up to 50,000 acres may be involved over a 30-year period. Permanence of such losses would be dependent upon the time required for and success of re-establishing useful wildlife food and cover. Additional research is needed on the re-establishment of indigenous wildlife food and cover plant species.

The impact of such habitat loss upon wildlife populations would occur principally in the loss of production capacity for the developed acres, which in turn would be reflected in lower populations of animals. For example, removal of critical winter browse would result in a corresponding reduction in mule deer numbers.

The drying up of surface water features, such as springs, seeps, and small streams, due to oil shale-related changes in ground-water patterns, would result in changes in the natural plant-animal complex associated with each particular water feature, including the related distribution of big game, wild horses and cattle.

d. Erosion

The areas stripped of natural cover with oil shale development would be vulnerable to wind and water erosion, until stabilized through vegetation or other means. Available information does not permit quantitative predictions of erosion extent. However, an average of 20,000 acres would be in active development as the industry grows to 1 million daily barrels and this area would be subject to erosion.

Both wind and water erosion would introduce sediment into surface waters. In aquatic habitat where resulting turbidity and siltation would exceed natural levels, adverse impact would occur in the form of lowered biological productivity, physical covering of fish spawning and nursery areas. The extent of such problematical erosion cannot be precisely predicted, since detailed information on pipeline routes, electric transmission lines, roads, etc., are not available at this time.

Vegetation adjacent to dirt roads and trails would be regularly cover with vehicle-caused dut if these are not paved. This would constitute a minor, but specific problem, since such vegetation would lose its wildlife food value until washed off by subsequent rains.

e. Degradation of Water Quality

The addition of sediment, leached substances and saline ground water in water released from excavations, overburden piles, spent shale piles, etc., to surface streams would, depending on the particular habitat and nature of polluting substances, result in adverse impacts upon aquatic plants and animals. Although such impacts cannot be quantitatively predicted, they are expected to be minor. Information is not available at this time on the volumes, chemical composition and locations of the proposed discharges to rivers, streams, lakes, etc. Unless carefully controlled, such discharges could have significant adverse effects on sections of the Green and White Rivers and other aquatic habitat in the area.

f. Oil Losses

In Chapter I, it was estimated that about 150 miles of new pipeline will be required to transport 1 million barrels of shale oil daily to major existing petroleum pipelines. This increase in pipeline mileage will bring with it attendant risks of oil spills due to pipeline losses caused by corrosion of pipe, equipment damage and the like. The average quantity of oil spilled due to transportation by these new pipelines would be relatively small, (estimated to average abouth 1 barrel per year), although the danger of a large volume spill does always exist.

In the event that an accidental loss were to occur, the oil would follow natural drainage features. Oil would result in mortality to trees, shrubs, and other vegetation with which it came into contact and adverse effects would also occur to birds, particularly waterfowl, some species of both land and water mammals, and fish and other aquatic organisms with which the oil came into contact.

g. Herbicides, Pesticides

Chemical control of insects, birds, mammals, or plants would result in the introduction of the control agents into the oil shale ecosystem. It is reasonable to assume that the expected volume and types of chemicals finding their way into the food chain from oil shale operations themselves would not result in significant adverse impacts upon the region's plants and animals. However, oil shale-related control programs, resulting from community pest problems, have a potential to use large volumes of chemicals. For example, mosquitoes are quite abundant in the vicinity of the Piceance Creek and present a potential pest problem which could require chemical control. Biological side-effects would be dependent upon the volume and types of chemicals used and the methods of application and disposal.

h. Fires

With the projected increases in human population, the frequency of man-caused fires would increase. However, it is possible that a combination of increased detection and access provided by new roads would result in an overall reduction in burned areas through more efficient control. The net effect could be a lowering of total acreage burned each year over the oil shale country as a whole.

Wild fires result in a temporary loss of wildlife food and cover, although the burnings are in some cases beneifical through a resulting regrowth of improved browse.

2. Urbanization and Human Pressures

a. Urbanization

Urbanization associated with a regional oil shale development would result in significant, but presently unquantifiable adverse impacts upon fish and wildlife and their habitat. Increased human habitation and activities and easier access would bring more people in closer contact with wildlife resources. This contact would result in disturbance and stress on wildlife population. This disturbance would be essentially the same as that already discussed under part D-1 of this section, "Impacts of Oil Shale Operations," but would occur on a broad regional scale. Development and increased human habitation would result also in some reduction in surface water quality near population centers as a result of sewage, toxic substances and siltation with resultant effects on aquatic habitat and organisms. Increased ground vehicle traffic would result in more frequent road kills of deer and other game.

b. Hunting and Angling Pressures

Without regional oil shale development, projections indicate that gross hunting demand in year 2000 in Colorado, Utah, and Wyoming portions of the Upper Colorado River region will approximate 1.4 million hunter days, while available hunting opportunity would be 2.6 million hunter days (10). The 1.2 million hunter day excess would probably absorb most of the additional hunting pressures, which would be generated by a regional oil shale industry.

Such increased use would create localized adverse impacts upon both game populations and quality of the hunting experience. Resulting increases in hunting pressure would have the potential to significantly reduce game populations, thus requiring additional regulatory management steps. For rabbits, snowshoe hares, ptarmigan, ruffed grouse, and mourning doves, which are presently not hunted near their population capacities, such reductions in numbers would probably not be harmful. However, increases in kill of mule deer, elk, moose, and antelope would require careful regulation in order to avoid undesirable downward population trends. Region-wide increased hunting pressure would have the most potential for impact upon very low abundance species, such as brown bear and cougar.

Without regional oil shale development, projections indicate that angling demand in the year 2000 in Upper Colorado River region portions of Colorado, Utah and Wyoming will approximate 5 million man-days annually, while available angling opportunity would be 10 million man-days (7). Thus, it appears that the angling opportunity available at that time would readily accommodate additional regional angling demand generated by oil shale-related population growth.

Finally, a predictable decrease in the quality of both angling and hunting experience would occur wherever intensified use resulted in fewer and/or smaller fish and game and the physical presence of more hunters or fisherman. Under these circumstances specific fish or wild life management plans would probably be required to adjust or alleviate such problems.

c. Impacts Upon Rare and Endangered Species

Development and associated urbanization, which would accompany a regional oil shale industry in the Upper Colorado River region would compound the impact of these factors which have resulted in the rare and endangered status of several species. If oil shale-related impoundments were constructed on the fast water streams of the humpback chub and and Colorado River squaw fish, both habitat and numbers of these species would be reduced. Unless carefully regulated, introduction of pesticides into localized ecosystems could affect the reproductive capability of the few remaining peregrine and prairie falcons.

E. Impact on Agriculture and Grazing

The oil shale lands themselves are not agricultural in the sense that they are not generally suited to cultivation. They are, however, subject to livestock use under grazing lease or permit from the Department's Bureau of Land Management. As with other mineral leasing, the use of the surface for grazing would not be precluded by oil shale lease issuance. Normally, the surface use would continue, except for areas undergoing active development, mining, or production as well as areas used for plant sites, access roads, and other similar uses. Possibly, where canyons and gullies would be used as disposal sites, there could be some enhancement in their appearance and agricultural usefulness as a result of the contouring, fertilization, revegetation, and stabilization which would all be part of surface restoration operations.

Leasing of public oil shale lands could have an indirect impact on private land farming activities, if cultivated lands adjacent to existing communities are converted to business or residential use as those communities expand. It is very difficult at present to accurately estimate the total acreage which might be affected in that way, but it may approximate 15,000 to 20,000 acres for a 1 million barrels per day industry.

An initial loss of grazing capacity on the leased lands cannot be avoided. This will result in varying degress of economic loss to the livestockman, depending upon the extent to which private base ranches or other lands can provide additional grazing, the type of mining done, and the success of revegetation efforts.

Factors affecting the surface include the open pit excavation, the area used for stockpiling mined ore which is to be fed into the plant, desposition of the spent shale, and the location of plant, storage, and related facilities and improvements. All of these surface utilizing factors must be coordinated such that various portions of the land surface can be continuously rehabilitated and revegetated as operations permit during the life of the lease. The long term effect of industrialization, however, would be some reduction of forest and brush cover.

The type of mining method or combination of methods used on the tracts has a bearing on the total number of acres affected, on- and off-tract. Of those total acres affected, those acreages occupied by the plant, storage, and related facilities and improvements, including roads, would be unavailable for grazing during the life of the lease. Acreages that would be temporarily unavailable for grazing, which could average 20,000 acres for the 1 million barrels per day industry, would include those lands where filling of overburden and spent shale was in process as well as area of active mining. These acreages would be rehabilitated and revegetated as operations would permit, thus rendéring them available for grazing during the life of the lease.

For instance, at the end of 30 years of lease operation, and depending on the mining methods used, the average annual loss of AUMs 1/ would range from an estimated 60 to 260 while that acreage put back into grazing production because of restoration and revegetation would range from an estimated 60 to 270 AUMs per year. For the other tracts, at the end of 30 years of lease operation, and depending on the mining methods used, the annual loss of AUMs would range from 275 to 317 while that acreage put back into grazing production because of restoration and revegetation would range from 275 to 1,080 AUMs (animal unit months) per year.

Some disturbance to the grazing animals will take place because of construction, mining and operations activity. A larger population density as a result of the project would increase the probability of animal disturbance from recreation and possibly theft. These may reflect in lowered total meat production. Any existing wild horses will be disrupted and they may be forced to other areas away from the program site.

There would be some additional effect on grazing in the areas (on and off lease tract) adjacent to the actual mining and retorting operations. Such activity may disturb livestock, which could result in lowered meat production.

1/ Animal Unit Months.

F. Impact on Aesthetic, Recreation, and Cultural Values

Oil shale development will disturb the total landscape, first in localized areas, and then over most of the tract areas. With disturbance of the landscape there would be loss of wildlife and their associated habitats (brought about by a reduction in land area and increased siltation of streams) which provide the major recreation resources of hunting, camping, fishing, and scenery to the Basins involved. The degree or amount of the impact upon the recreation and associated aesthetic resources and activities would depend upon the following:

(a) The present condition of the existing landscape and the location of the deposit;

(b) The method(s) of mining; open pit mining would create the most severe adverse impact with an estimated 5 thousand acres being directly affected over a 20-year period, underground mining would directly affect some 1,100 acres over the same period of time; and

(c) The success of rehabilitating the affected areas.

Areas that would be most affected scenically include: Gathedral Bluffs, Piceance Creek, sections of the Green River, Sand Wash Historical Landmark, Book Cliffs, and Kinney Rim. With the proposed projects, the general landscape would be changed from a quite "natural" asymmetric type to a symmetric landscape with buildings, roads, trails, pipelines, powerlines and cleared rights-of-way.

Archaelogical and historical values along the White River in Utah are known to exist adjacent to the proposed project oil shale lands.

Examples include the Freemont Indian Culture, ghost towns of Rainbow and Watson, abandoned sections of the Uintah Railroad, and the old crossings of Ignacio Stage Stop and Old Uridge, Kinney Rim in Wyoming is in the heart of the historic Wind River Shoshone and Commanche country. Indications are that campsite and animal kill sites will be found in this particular Basin dating from present to historic times dating 10,000 years back. All of these areas could be affected directly (onsite) or indirectly (offsite) as the proposed projects are developed.

Any development would result in the following impacts:

(1) Clear air would be somewhat degraded by dust from mining operations onsite as well as offsite on roads and other urban like facilities;

(2) Visual impact from disposal of spent shale disposal would be notable until restoration activities are completed; approximately 15,000 acres would be affected by industry development.

(3) Visual impact on the asymmetric landscape would be impaired by utility rights-of-way such as: pipelines, powelines, roads and trails.

(4) An oil shale industry would probably have little impact on the recreation of the tracts during the first few years. As the development progresses it is estimated that approximately 5 percent (for underground operations) to 25 to 50 percent (for surface operations) of the recreation potential in and around the sites to be developed would be lost due to loss of wildlife habitat as well as the movement of wildlife species to other areas. Associated recreation activities that would be affected

including camping, sightseeing, and rock hounding.

(5) Deer hunters and other types of recreationists would be forced to use "other" areas in or adjacent to the development sites thereby, creating increases in hunter and other recreation use densities on the "other" areas. By such action the existing quality on the "other" areas would be reduced.

(6) Improved accessibility created by the proposed projects would create moderate increases in outdoor recreation activities throughout the Basins on both public and private lands.

(7) With the development of the open-pit operation it could provide a scenic vista which could increase tourist traffic beyond that associated with normal outdoor recreation activities.

Widespread use of chemicals are not anticipated but should their use be necessary, proper storage, use, and disposal or resale will be required so as not to cause environmental degradation.

The impact on outdoor recreation and its associated aesthetic and cultural values is directly related to the refuse generated from mining and processing as well as the amount of land disturbed by the mining process used. The refuse will require proper disposal so as to have the least damaging effect upon the environment. For example, junk equipment should be sold for scrap rather than buried, combustible materials should be disposed of under approved methods, excess chemicals should be disposed of by burying, or sold; spent oil and lubricants should be held in storage for recycling. The degree or amount of impact is also directly related to the present condition of the landscapes as they pertain to the depth of the oil shale deposits and the sucess of rehabilitating the affected areas. It is anticipated that the proposed projects will create better access and open up new areas for outdoor recreation. However, better access will create an increase in traffic, litter, and vandalism which could reduce the quality of the recreation experience. Therefore, in order to maintain, preserve and improve the essential aesthetic resources of the Oil Shale Basins intensive engineering, soil and conservation management practices, and structures will be necessary for the proposed project areas.

G. Impact on Existing Economic and Social Environment

1. Overall Regional Impact

Oil shale development will generate within the region both permanent and temporary employment. Extensive flows of capital into andout of the region will also occur as the equipment and services needed to sustain the operations are utilized. A number of assumptions must be made to study this potential economic impact. Although the assumptions could be varied, the cumulative effect of development on both private and public lands presented in this review is based upon what are considered to be reasonable projections and assumptions, and to provide an indication of the urban planning needed to facilitate this new industry (8).

a. Sequence of Development

The sequence of development has previously been presented (Table III-2). However, the analysis which follows is directly related to the site location and pertains only to that development prior to 1982 with extrapolation of the data to 1985 as warranted. The location of the plants that may be built beyond 1981 cannot now be estimated.

b. Employment and population

Development of oil shale will create both temporary and permanent employment, a factor which must be considered in regional development plans.

(1) Temporary - All temporary employment will be associated with the construction of the plants and urban communities. Temporary support employment would be required to provide services to these construction employees. These jobs would be temporary only in the sense that the job terminates with the completion of the construction. As long as the industry continues to develop, shifting of construction personnel should take place between the different plant sites. Thus, as shown in Table III - 9, total temporary employment would increase from abouth 2,700 in 1973 to about 12,000 in 1977. Plants to be built beyond the 400,000 barrel per day capacity specifically projected for the 1973-1981 period could maintain construction employment in this neighborhood. Table III-5 only considers the employment associated with this first 400,000 barrel per day capacity.

Table III-9 Colorado, Utah and Wyoming--Oil Shale Temporary and Permanent Employment, Temporary and Permanent Population

	Temporary Employment				Permanent Employment			Population 6/		
	Plant 1/ Construction	Urban 2/ Construction	Support 3/4/	Total	Plant	Support 3/4/	Total	Temporary	Permanent	Total
1973	975	694	1,051	2,720				6,631		6,631
1974	975	694	1,051	2,720				6,631		6,631
1975	2,925	2,082	3,153	8,160				19,893		19,893
1976	3,375	2,368	3,617	9,360	1,290	993	2,283	22,819	6,164	28,983
1977	4,350	3,062	4,668	12,080	1,290	993	2,283	29,450	6,164	35,614
1978	3,925	3,131	4,476	11,532	3,870	2,979	6,849	28,236	18,492	46,728
1979	2,500	2,201	2,961	7,662	5,690	4,380	10,070	18,679	27,191	45,403
1980	1,525	1,507	1,910	4,942	6,980	5,373	12,353	12,048	33,355	46,738
1981					9,780	7,529	17,309		46,738	46,738

1/ Source: Bureau of Mines. The number of operating employees per unit of shale oil produced will decrease as the size of the plants increases.

2/ Derived from value of labor for urban construction, see Table 5, footnote 1.

3/ Assumes 1.37 employed people per new household.

4/ Based on employment multiplier of 0.63 times temporary plant plus urban employment; Source: Same as footnote 5, but modified to reflect the experience that 1/4 of all construction support workers will not bring their families into the region.

5/ Based on employment multiplier of 0.77 times permanent plant employment, Source: Consulting Services Corp., for the Public Land Law Review Commission, Study of Impact of Public Funds on Selected Regional Economics, April, 1969,p.104.

6/ Based on a family size of 3.7 persons; Source: Bureau of Census data for Colorado, Utah, and Wyoming.

(2) Permanent.- All permanent employment would be associated with the daily operation of the plants and in providing supporting services. As shown in Table III-9, permanent employment would increase as additional plants come on stream, reaching approximately 17,300 in 1981. These plants will of course operate beyond 1981 and employment at each plant would remain at the level attained in 1981.

(3) Population.- As shown in Table III-9, the total employment associated with oil shale development and the families of these new employees should result in the population of the region growing by nearly 47,000 people in the 1973-81 period. The 400,000 barrel per day capacity operating in 1981 will continue to support this 47,000 additional population as long as these plants operate.

(4) Current Employment and Population.- In the seven counties which comprise the oil shale region, the population in 1970 was about 119,000, of which 44,000 were employed (Table III-10). The creation of over 17,000 new permanent jobs cannot be satisfied from the existing population, and therefore a migration into the region would result. Over a 9-year period, the total population of the area would thus increase by 40 percent.

Table III-10 Population and Labor Force of Counties Within the Oil Shale Region, 1970.

	Population	Total Employment 16 and over	Percent Unemployed
	Thousands of People		
Colorado:			
Garfield	14.8	5.9	4.9
Mesa	54.3	20.1	5.4
Rio Blanco	4.8	1.9	2.1
Utah:			
Duchesne	7.3	2.4	4.6
Uintah	12.7	4.0	7.0
Wyoming:			
Sweetwater	18.4	7.0	4.4
Uinta	7.1	2.6	4.6
Total	119.4	43.9	4.9

Source: 1970 Census of Population, General Social and Economic characteristics. Burau of Census.

c. Expenditure Flows

The oil shale industry should stimulate expenditures for both plant equipment and urban facilities. Significant payment of money to the employees (as salaries), and to Federal, State, and local governments (as taxes and other revenues) would also be produced.

(1) Plant and Urban Construction.- The cost of the oil shale plant depends upon both the technology used and the size of the expected output (Table III-11). These data and the previously described development schedule (Table III-2), were used to estimate annual plant equipment purchases from 1973 to 1981 (Table III-12). Over $1.4 billion would probably be spent over this time period for the equipment needed to produce a 400,000-barrel-per-day shale oil output from both private and public leases.

Urban construction would be required to house and provide support to the new employment stimulated by this industry. Development will occur primarily in the existing urban centers which are most convenient to the plant locations. Rock Springs, Wyoming, Vernal, Utah, and Rangely and Grand Junction, Colorado, will probably be the major centers of initial growth and development. Urban construction would probably take place concurrently with plant construction, in order for the urban facilities to be available for the operating employees when the plant construction

Table III-11 Oil Shale Capital and Operating Costs.
Note - These estimates, which include general environmental safeguards, may be expected to vary at least 10 percent.

Millions of Dollars		
Mining option	Plant carcaity,[1/] thousand bbl/day 50	100
Underground with Mine Disposal		
Capital costs:		
Labor	35.2	
Equipment	187.2	
Total	222.4	
Annual operating costs:		
Labor	11.2	
Supplies	14.9	
Total	26.1	
Open Pit with Backfill		
Capital costs:		
Labor		51.2
Equipment		267.8
Total		319.0
Annual operating costs:		
Labor		15.8
Supplies		17.9
Total		33.7
In Situ (non-nuclear fracturing)		
Capital costs:		
Labor	19.8	--
Equipment	213.9	--
Total	233.7	--
Annual operating costs:		
Labor	13.1	--
Supplies	2.1	--
Total	15.8	--

1/ Except for in situ, capacity is based on Bureau of Mines gas combustion retort and is in terms of semirefined shale oil and 1970 dollars.

Table III-12

Plant Equipment and Urban Materials[1/] Purchased
Million of Dollars

	Plant equipment	Urban Materials	Total
1973	62.4	16.7	79.1
1974	62.4	16.7	79.1
1975	187.2	50.1	237.3
1976	214.1	56.9	271.0
1977	276.5	73.6	350.1
1978	285.4	76.4	361.8
1979	196.1	52.9	249.0
1980	133.7	36.2	169.9
	1,417.8	379.5	1,797.3

1/ Urban construction is estimated at $45,000 capital cost per household for new residential, commercial, and community facilities. Of this total, $30,000 is allocated to materials and $15,000 to labor.

would be completed. In calculating the amount of urban materials that would be purchased (Table III-12),it has been assumed that no appreciable capital investment would be made for the benefit of temporary construction employees that cannot be used by the permanent operating employees. As shown,nearly $380 million may be spent for urban construction materials over the 1973-80 period.

Because a limited manufacturing base currently exists within the seven counties that comprise the oil shale region, it has been assumed that nearly all plant and urban construction materials would be purchased outside the region during this period. Together, these expenditures (Table III-12),would total about $1.8 billion over the eight-year period beginning in 1973.

(2) Employee Incomes.- The projected amount of salary spent was used to approximate the income that would be spent within the region, an assumption that would be true only if the total value of tax payments leaving the region equals the value of the profits that remain. As shown in Table III-13about $600 million would be paid as salaries to construction and construction support employees through 1981. Of the $1.0 billion total, $0.9 billion, or 90 percent of the gross salaries, should remain within the oil shale region.

Table III-13 Salaries and Distribution: Colorado, Utah and Wyoming

Millions of Dollars

	Gross Salaries					Salaries spent 4/ within region
	Construction 1/	Construction 1/ Support	Operating 2/	Urban 3/ Support	Total	
1973	20.0	7.9			27.9	24.1
1974	20.0	7.9			27.9	24.1
1975	60.0	23.7			83.7	72.3
1976	68.9	27.2	11.2	7.4	114.7	101.7
1977	88.9	35.1	11.2	7.4	142.6	125.8
1978	85.3	33.6	33.6	22.2	174.7	158.6
1979	56.4	22.2	49.4	32.7	160.7	150.0
1980	36.4	14.3	60.6	40.1	151.4	144.5
1981			84.9	56.2	141.1	141.1
	435.9	171.9	250.9	166.0	1,024.7	942.2

1/ Plant and urban construction salaries assumed to be $12,000 per man year.

2/ Operating salaries assumed to range from $8,600 to $9,700 per man per year depending on the size of the plant.

3/ All support salaries were estimated at $7,500 per man-year.

4/ Assumes that one quarter of the construction workers will not bring their families into the region and that these workers will spend only one quarter of their salaries in the region.

(3) Tax Flows.- Total taxes and public revenues should increase to about $300 million per year by 1981 (Table III-14). These amounts would accrue as follows: 71 percent to the Federal Government, 11 percent to State and 18 percent to local governments. The annual Federal share by 1981 would be $220 million, derived mainly from the income tax payments of shale oil producers and from personal income tax. State revenues would reach $34 million per year by 1981, derived mainly from State income tax on oil shale profits ($19 million) and that portion of the royalty payment rebated to the States ($7 million). Individual income tax, other business income tax and sales tax make up the remaining $8 million. Use tax on construction material appears as zero in 1981 since no construction associated with the 400,000 barrel per day capacity will be underway in 1981.

Local taxes, which are essentially property taxes, would total $54 million in 1981. The oil shale producers would pay $3 million tax on resource value and $40 million on plant value. Taxes on other private property would add another $11 million. As the industry grows beyond the 400,000 barrel per day level, tax revenues should increase proportionately.

Table III-14 Taxes and Public Revenues: Colorado, Utah and Wyoming

	Millions of Dollars			
	Federal	State 1/	Local 1/	Total
1973	3.5	3.5	--	7.0
1974	3.5	3.5	--	7.0
1975	10.5	10.3	--	20.8
1976	39.8	15.4	10.7	65.9
1977	43.3	19.1	10.7	73.1
1978	100.4	27.7	21.4	149.5
1979	139.8	30.7	32.0	202.5
1980	166.4	31.9	39.1	237.4
1981	219.5	33.7	53.8	307.0
	726.7	175.8	167.7	1,070.2

1/ State and local tax rates applicable in Colorado were used to estimate regional tax revenues. Federal revenues are independent of State location of plant sites.

(4) Distribution of bonuses, rents and royalties received by the Federal government.

The monies collected by the Federal Government as bonuses, rents, and royalties from oil shale leases are redistributed among the County, State and Federal governments for specific uses established by law.

The Mineral Leasing Act of 1920 provides in Section 35:

> "That 10 per centum of all money received from sales, bonuses, royalties, and rentals under the provisions of this Act excepting those from Alaska, shall be paid into the Treasury of the United States and credited to miscellaneous receipts; for the past production 70 per centum, and for future production 52½ per centum of the amounts derived from such bonuses, royalties, and rentals shall be paid into, reserved, and appropriated as a part of the reclamation fund created by the Act of Congress, known as the Reclamation Act, approved June 17, 1902, and for past production 20 per centum, and for future production 37½ per centum of the amounts derived from such bonuses, royalties, and rentals shall be paid by the Secretary of the Treasury after the expiration of each fiscal year to the State within the boundaries of which the leased lands or deposits are or were located, such monies to be used by such State or subdivisions thereof for the construction and maintenance of public roads or for the support of public schools or other public educational institutions, as the legislature of the State may direct."

The 52½ percent paid into the reclamation fund is used for "the examination and survey for and the construction and maintenance of irrigation works for the storage, diversion, and development of waters for the reclamation of arid and semiarid lands in the said States and Territories, and in the State of Texas, and for the payment of all other expenditures provided for in" the Reclamation Act of 1902. (USC Title 43 § 391)

The 37½ percent that is paid to the States is allocated by Colorado, Utah, and Wyoming as follows:

Colorado

33.3% to the State public school fund

66.7% to the county from which it was derived to be used for public schools or public roads but not more than 75% to either use in any one year.

Utah

90% of the monies received shall go into the uniform school fund to support the public schools of the State

10% shall be allocated to the county in which the mineral was produced to be used for road purposes.

Wyoming

3% to originating county for roads

3% to State Highway Commission for road work in originating county

35% to State for roads

50% credited to the foundation program fund for the public schools

9% credited to the University of Wyoming.

d. Urban Development

The development of 400,000 barrels of shale oil capacity by 1981 would increase the population of the area by 40 percent. Some of the small towns would grow to several times their current size. Larger cities, with over 10,000 population, could almost double in size.

In the calculation of construction salaries and purchases of construction materials, $2,700 per person has been allowed for the capital cost of new public construction. This is a liberal allocation in view of the estimated costs of some of the more important individual public capital costs. Schools are estimated (8) to cost $350 per person, hospitals $120 per person, water treatment and distribution $150 per person, and sewerage disposal $150 per person.

Local property taxes are estimated to total about $1,150 per person per year of which 80 percent would come from payments on the oil shale facilities. Thus, overall local tax revenues should be large enough to amortize the required urban capital expenditures. In order to obtain orderly and suitable development, however, advance planning and authority to implement these plans will be needed.

There will be a lag between the time when expenditures will need to be made for public construction and the time when property tax revenues become available to amortize these expenditures. (Table III-15). The financing of public expenditures by municipal bonds is the usual way of overcoming this lag.

An additional problem of municipal financing will arise when the urban development associated with an oil shale plant is not in the same county as the plant. Since the plant will contribute 80 percent of the new local tax revenues, urban development will be difficult to finance without access to the taxes generated by the plan.

e. Social and Community Impacts

The predominantly rural oil shale region will be changed by the prototype leasing program. The changes will not only occur in the physical environment, but will also occur in the community structures and organizations, in the economic and political systems of the area and perhaps most importantly, in the social structures or lifestyles of all the people involved. The latter changes may very well be the most significant for changing patterns of behavior will also effect changes in the surrounding environs; these additional changes are the most difficult to quantify. In some ways it may be said that measurement of these impacts is measurement of the quality of life.

Table III-15 Public Construction Expenditures and Tax Receipts:1/ Colorado, Utah and Wyoming

Year	Tax Receipts	New Public Construction Expenditures
1973	-	5.6
1974	-	5.6
1975	-	16.7
1976	10.7	19.0
1977	10.7	24.5
1978	21.4	25.5
1979	32.0	17.6
1980	39.1	12.1
1981	53.8	-
	167.7	126.6

1/ On the basis of $10,000 per permanent population family.

The influx of 47,000 new inhabitants to the area will have the most visible impact on the social and community structures. For the most part, these people will migrate from more urbanized and densely populated regions. They will expect certain amenities and conveniences, and patterns of living which will not be readily available in the oil shale region. This may be a relatively simple adjustment for some of the immigrants to make. Others will not want to or be as capable of making the adjustments even for a relatively short period of time and will influence the worker turnover rate.

The influx of those new residents, however, will have the greatest impact on the original inhabitants of the area. Over the leasing period, their life-styles will change. The advent of a new industry and new employers represents technological progress, and any progress or change in one section of the society will initiate change in the social sector. However, a period of adjustment and cultural lag normally follows in which disorientation of people (and sometimes policies) occurs due to the naturally slower rate of social change.

The transformation from a semi-rural environment to an industrialized one will mean a faster, more croweded pace of life at the very least. It will increase crime rates (Table III-16), change recreation patterns to more sophisticated urbanized (and more costly) styles, and will probably influence the unemployment rate for many people migrate to new areas of development looking for something better. These changes because they represent changes in living patterns, cannot be adequately evaluated,

Table III-16 U.S. Crime Rate in 1969

(number per 100,000 population)

City Size	Violent Crime	Property Crime
Rural	100	1,150
Under 10 thous.	110	2,200
10-25 thous.	140	2,750
25-50 thous.	170	3,200

Source: Department of Justice, Federal Bureau of Investigation. Uniform Crime Reports for the U.S., 1969.

however, because to do so would represent a value judgement on life styles. However, looking at the total time span and looking at other communities' ability to adjust to changes brought about by industrial or technical progress, the total impact on living patterns will probably be negligible.

There are a few problems which may be encountered during the period of industrialization which should at least be mentioned. In terms of social change, they are merely administrative items which may or may not become major problem issues, depending upon the local governments and/or planning commission's handling of them. Within each state, planning commission have been established at the county level, and Colorado has also a State and Regional Planning Commission. In at least two of the states, Wyoming and Colorado, zoning and subdivision regulations are already in effect which, if properly administered, can ensure orederly physical growth and development. These regulations, which are explained in section IV, take into account the probable development of mobile home parks, and can also ensure environmental quality.

Two major problems which may arise during the construction period initially and may continue for some time during the production phase are inadequacies of housing facilities and the substantial increase in road usage between urban centers and plants sites. Transportation routes and road improvement and maintenance usually represent a major difficulty to local governments in a rapidly industrializing areas, as education and health facilities take priority and, in the beginning, public funds are limited.

The inadequacy of housing during the construction period especially may result in additional detrimental effects. The first effect could be over-crowding of existing facilities possibly creating health and safety hazards. Secondly, disproportionately high rents may also occur. This could affect the worker turnover rate. It is also expected that many of the workers, both construction and production, will bring mobile homes into the area. This could result in "shanty town" type developments; however, the regulations the planning commission have established will probably avert this development.

One additional area of concern which cannot be quantified is the differences and possible antagonisms between the original townspeople and the new immigrants. Though in many of the affected communities the immigrants will outnumber the original inhabitants, the immigrants would still be considered "new comers" and "outsiders."

Many of the inhabitants of these small communities chose and remained in this area to escape the pressures of urban living. They may resent immigrants because they represent increased urbanization. Stratification reflecting this attitude may be imposed by the inhabitants. A well-planned educational program will be necessary to minimize these antagonisms.

f. Health and Safety Impacts

The development of any new mine on either public or private lands would require prior approval by applicable Federal and State laws. Once development is begun, the mine would be periodically inspected to ensure compliance of the approved plan and enforcement of all Federal and State mine health and safety regulations.

An estimated 1.6 million tons of oil shale were mined in experimental operations by both the Bureau of Mines and industry. Although no fatalities were incurred during any of these operations, it is generally accepted that any form of mining does have the potential to incur hazards in the form of fatalities, injuries and/or impaired health.

It is difficult to assess the potential for health and safety hazards because there are no real comparable statistics available. Oil shale development can utlilize underground and surface (open-pit) operations as well as in situ recovery. Though health and safety statistics are available for both underground and surface mining operations, the technologies involved in oil shale mining and processing makes it anticipated to be more closely alligned to surface mining in terms of fatality and accident rates.

The trend in surface mining operations over the past ten years has been a reduction in fatalities. In many respects this is due to a combination of more stringent Federal and State laws and improved technologies. Between 1960 and 1969, the mine fatality rate per million tons in coal surface mining operations averaged 0.13. Applying this same rate of fatalities to the 8.5 billion tons of oil shale that could be mined through 1985, 1,100 fatalities could occur as a direct result of oil shale development.

Newly updated and greatly strengthened laws as well as substantially increased staffing by the U. S. Bureau of Mines and States Industrial Commission inspection teams should now be sufficient to promote and maintain adequate health and safety standards. Metal and non-metallic Mine Health and Safety standards as contained in 30 CFR Parts, 55, 56, and SF, will apply to all operations involving the extraction of oil shale.

In addition, as part of a comprehensive program in mine health and safety, the Bureau of Minesis conducting extensive research on mine safety, including the safe use of diesels underground. The result of this research will be available to help guide the evaluation of this new industry.

2. Impacts in Colorado

Development of the two prototype leases in Colorado is expected to result in a shale oil productive capacity of 50,000 barrels per day on one of the tracts with underground mining by 1978 and 100,000 barrels per day on the other with open-pit mining by 1979. In addition, oil shale plants on private lands in Colorado are projected at 50,000 barrels per day in 1976 with like amounts becoming operational in 1978 and 1981.

a. Employment and Population

The 50,000 barrel per day plant with underground mining that is projected for a Federal lease in Colorado in 1978 will have the same employment, population, salary, and tax impacts as are described for the plant to come on stream in Utah in 1980. All impacts from this plant in Colorado of course will occur two years ahead of the Utah plant. Construction of this plant in Colorado will begin in 1977 with the temporary population associated with construction increasing by 6631. When plant operation begins in 1980, the population increase of permanent residents will be 6164. The details of salaries and taxes can be found in the section describing Utah.

Construction of the 100,000-barrel per day plant is projected to begin in 1976. This construction will provide employment for 1425 for the three-year construction period. An additional 980 construction jobs will be provided by urban construction during the same period. Construction personnel and their families will generate employment for 1515 in supporting services. The overall population increase associated with the temporary employment for construction and construction support is estimated to be 9557.

When the plant is in operation permanent employment there is expected to be 1820. Permanent support employment after production begins is estimated at 1401. This is slightly below the level of temporary support employment and a considerable proportion of these permanent support positions can be expected to be held by those holding temporary support positions.

Total new permanent population associated with the 100,000 barrel/per day plant is estimated at 8699.

During the three-year construction period, expenditures for plant equipment and construction materials will average $113 million per year.

During the construction period, construction and support salaries will total $40.3 million per year. When operation of the plant begins, salary payments to operating personnel and the associated urban support personnel will be $26.3 million per year.

b. Expenditure Flows

The construction between 1973 and 1980 of the five oil shale plants projected for both Federal and non-Federal lands in Colorado will provide employment for up to 9360 people. The peak in temporary employment for this group of plants will occur in 1976 and 1977. Additional construction in Colorado would keep the level of construction personnel from falling as shown in the attached tables. The population associated with the 9360 temporary employment would be 22,819.

Permanent employment at shale oil plants will start at 1290 in 1976 with the start-up of the first plant. It will reach 6980 in 1981 when the fifth plant comes on stream. Support employment will bring total new employment in 1981 up to 12,353 and new population up to 33,355 (Table III-17) This compares with a 1970 population of 73,900 in the three affected counties of Colorado.

Expenditures for plant equipment and urban construction materials will total nearly $1.3 billion between 1973 and 1980, reaching a peak of $271 million per year in 1976 and 1977 (Table III-18) These materials and equipment are assumed to be brought in from outside the oil shale area.

Table III-17 Colorado--Oil Shale Temporary and Permanent Employment, Temporary and Permanent Population

	Temporary Employment				Permanent Employment			Population 6/		
	Plant 1/ Construction	Urban 2/ Construction	Support 3/4/	Total	Plant	Support 3/5/	Total	Temporary	Permanent	Total
1973	975	694	1051	2720				6631		6631
1974	975	694	1051	2720				6631		6631
1975	2925	2082	3153	8160				19893		19893
1976	3375	2368	3617	9360	1290	993	2283	22819	6164	28983
1977	3375	2368	3617	9360	1290	993	2283	22819	6164	28983
1978	2400	1674	2566	6640	3870	2979	6849	16188	18492	34680
1979	975	694	1051	2720	5690	4380	10070	6631	27191	33822
1980	975	694	1051	2720	5690	4380	10070	6631	27191	33822
1981					6980	5373	12353		33355	33355

1/ Source: Bureau of Mines.

2/ Derived from value of labor for urban construction, see Table 2, footnote 1.

3/ Assumes 1.37 employed people per new household.

4/ Based on employment multiplier of 0.63 times temporary plant plus urban employment; Source: Same as footnote 5, but modified to reflect the experience that 1/4 of all construction support workers will not bring their families into the region.

5/ Based on employment multiplier of 0.77 times permanent plant employment, Source: Consulting Services Corporation, for the Public Land Law Review Commission, Study of Impact of Public Funds on Selected Regional Economics, April, 1969, p. 104.

6/ Based on a family size of 3.7 persons; Source: Bureau of Census data for Colorado, Utah, and Wyoming.

Table III-18 Colorado--Plant Equipment and Urban Materials 1/ Purchased

	Millions of Dollars		
	Plant equipment	Urban materials	Total
1973	62.4	16.7	79.1
1974	62.4	16.7	79.1
1975	187.2	50.1	237.3
1976	214.1	56.9	271.0
1977	214.1	56.9	271.0
1978	151.7	40.2	191.9
1979	62.4	16.7	79.1
1980	62.4	16.7	79.1
1981			
	1016.7	270.9	1287.6

1/ Urban construction is estimated at $45,000 capital cost per household for new residential, commercial, and community facilities. Of this total, $30,000 is allocated to materials and $15,000 to labor.

Salaries paid to all types of employees, construction, construction support, operating, and urban support will reach a peak of $124 million per year in 1978 and then level off at $101 million per year when construction is completed (Table III-17).

Federal revenues generated by the oil shale industry will build up to $158 million per year by 1981, mainly from the corporate income taxes of the oil shale industry. Likewise, State revenues, which will reach $24 million in 1981, will be mainly from the State income tax of the shale oil industry. Local taxes of $39 million per year by 1981 will result mainly from property taxes on oil shale facilities (Table III-18).

3. Impacts in Utah

Development of two prototype leases in Utah is projected to result in a shale oil productive capacity of 50,000 barrels per day by 1980 using underground mining. Construction of this capacity and of the required additional urban facilities would begin in 1977. Some of the additional urban facilities might be constructed in Colorado if Rangely, Colorado, becomes the residence for some portion of the plant's employees.

Table III-19 Colorado--Salaries and Distribution

	Million of Dollars					
	Construc-1/ tion (Plant)	Construc-1/ tion (Urban)	Oper- 2/ ating	Urban 3/ Support	Total	Salaries spent 4/ within region
1973	20.0	7.9			27.9	24.1
1974	20.0	7.9			27.9	24.1
1975	60.0	23.7			83.7	72.3
1976	68.9	27.2	11.2	7.4	114.7	101.7
1977	68.9	27.2	11.2	7.4	114.7	101.7
1978	48.9	19.3	33.6	22.2	124.0	114.8
1979	20.0	7.9	49.4	32.7	110.0	106.2
1980	20.0	7.9	49.4	32.7	110.0	106.2
1981			60.6	40.1	100.7	100.7

1/ Plant and urban construction salaries assumed to be $12,000 per man year.

2/ Operating salaries assumed to range from $8,600 to $9,700 per man per year depending on the size of the plant.

3/ All support salaries were estimated at $7,500 per man-year.

4/ Assumes that one quarter of the construction workers will not bring their families into the region and that these workers will spend only one quarter of their salaries in the region.

Table III-20 Colorado----Taxes and Public Revenues Generated by Oil Shale Development

	Millions of Dollars			
	Federal	State 1/	Local 1/	Total
1973	3.5	3.5		7.0
1974	3.5	3.5		7.0
1975	10.5	10.3		20.8
1976	39.8	15.4	10.7	65.9
1977	39.8	15.4	10.7	65.9
1978	94.0	20.4	21.4	135.8
1979	133.4	23.4	32.0	188.8
1980	133.4	23.4	32.0	188.8
1981	157.6	23.5	39.1	220.2

1/ State and local tax rates applicable in Colorado were used to estimate regional tax revenues. Federal revenues are independent of State location of plant sites.

a. Employment and Population

Plant construction will provide employment for 975 construction employees during the three-year construction period. An additional 694 construction jobs will be provided by urban construction during the same period. These construction personnel and their families will generate employment for 1,051 in supporting services. The overall population increase associated with the temporary employment for construction and construction support is estimated to be 6,631.

When the plant is in operation permanent employment there is expected to be 1,290. This is about 400 less than the total construction employment. Personnel movement can be expected to be greater than this 400, however, since relatively few construction workers are expected to take positions as plant operators.

Permanent support employment after production begins is estimated at 993. This is approximately the same level of support employment as during construction and a considerable proportion of these permanent support positions may be held by the same personnel that held the temporary support positions.

Total new permanent population is estimated at 6,164 (Table III-19). This population increase compares with the existing population in Uintah County of 12,700, and a population of 20,000 in the two Utah counties.

Table III-21 Utah --Oil Shale Temporary and Permanent Employment, Temporary and Permanent Population

	Temporary Employment				Permanent Employment			Population 6/	
	Plant 1/ Construction	Urban 2/ Construction	Support 3/4/	Total	Plant	Support 3/4/	Total	Temporary	Permanent
1973									
1974									
1975									
1976									
1977	975	694	1,051	2,720				6,631	
1978	975	694	1,051	2,720				6,631	
1979	975	694	1,051	2,720				6,631	
1980					1,290	993	2,283		6,164
1981					1,290	993	2,283		6,164

1/ Source: Bureau of Mines.

2/ Derived from value of labor for urban construction, see Table 2, footnote 1.

3/ Assumes 1.37 employed people per new household.

4/ Based on employment multiplier of 0.63 times temporary plant plus urban employment; Source: Same as footnote 5, but modified to reflect the experience that 1/4 of all construction support workers will not bring their families into the region.

5/ Based on employment multiplier of 0.77 times permanent plant employment, Source: Consulting Services Corporation, for the Public Land Law Review Commission, Study of Impact of Public Funds on Selected Regional Economics, April, 1969, p. 104.

6/ Based on a family size of 3.7 persons; Source: Bureau of Census data for Colorado, Utah, and Wyoming.

b. Expenditure Flows

During the three-year construction period, expenditures for plant equipment and construction materials will average $79 million per year (Table III-22). Such equipment and materials are expected to be shipped in from outside the region.

During the construction period construction and support salaries will total $28 million per year. When operation of the plant begins, salary payments to operating personnel and the associated urban support personnel will be $18.6 million per year (Table III-23).

During the construction period, Federal tax revenues generated mainly from personal income tax will be $3.5 per year. State taxes will be $3.7 million per year mainly from the use tax on equipment and construction materials brought in from out-of-State.

When the plant is in operation Federal revenues will increase to $30 million per year, the increase being due to corporate income taxes and to royalty received on production. State revenues will be $4.9 million per year mainly from corporate income tax and the portion of royalty payments transferred to the State. Local taxes of $7.1 million per year will be collected as property taxes on the oil shale installation and on other residential and business properties (Table III- 24).

Table III-2 Utah--Plant Equipment and Urban Materials 1/ Purchased

	Millions of Dollars		
	Plant equipment	Urban materials	Total
1973			
1974			
1975			
1976			
1977	62.4	16.7	79.1
1978	62.4	16.7	79.1
1979	62.4	16.7	79.1
1980			
1981			

1/ Urban construction is estimated at $45,000 capital cost per household for new residential, commercial, and community facilities. Of this total, $30,000 is allocated to materials and $15,000 to labor.

Table III-23 Utah--Salaries and Distribution

	Millions of Dollars					
	Gross Salaries					Salaries spent 4/ within region
	Construction 1/ (Plant)	Construction 1/ (Urban)	Operating 2/	Urban 3/ support	Total	
1973						
1974						
1975						
1976						
1977	20.0	7.9			27.9	24.1
1978	20.0	7.9			27.9	24.1
1979	20.0	7.9			27.9	24.1
1980			11.2	7.4	18.6	18.6
1981			11.2	7.4	18.6	18.6

1/ Plant and urban construction salaries assumed to be $12,000 per man year.

2/ Operating salaries assumed to range from $8,600 to $9,700 per man per year depending on the size of the plant.

3/ All support salaries were estimated at $7,500 per man-year.

4/ Assumes that one quarter of the construction workers will not bring their families into the region and that these workers will spend only one quarter of their salaries in the region.

Table III-24 Utah--Taxes and Public Revenues Generated by Oil Shale Development

	Millions of Dollars			
	Federal	State 1/	Local 1/	Total
1973				
1974				
1975				
1976				
1977	3.5	3.7		7.2
1978	3.5	3.7		7.2
1979	3.5	3.7		7.2
1980	30.1	4.9	7.1	42.1
1981	30.1	4.9	7.1	42.1

1/ State and local tax rates applicable in Colorado were used to estimate regional tax revenues. Federal revenues are independent of State location of plant sites.

4. Impacts in Wyoming

Development of two prototype leases in Wyoming is projected to result in a shale oil productive capacity of 50,000 barrels per day by 1981 using in-situ retorting. Construction of this capacity and of the required additional urban facilities would begin in 1978.

a. Employment and Population

Plant construction will provide employment for 550 construction employees during the three-year construction period. An additional 813 construction jobs will be provided by urban construction during the same period. These construction personnel and their families will generate employment for 859 people in supporting services. The overall population increase associated with the temporary employment during construction is estimated to be 2222.

When the plant is in operation, permanent employment there is expected to be 1510. Permanent support employment is estimated to be 1163. This is a larger support employment than during construction. A considerable proportion of the personnel in support jobs during construction can be expected to remain and fill the permanent support jobs.

Total new permanent population is estimated at 7219 (Table III-25). This population increase compares with an existing population in Sweetwater County of 18,400 and in Uinta County of 7100.

Table III-25 Wyoming --Oil Shale Temporary and Permanent Employment, Temporary and Permanent Population

	Temporary Employment				Permanent Employment			Population 6/	
	Plant 1/ Construction	Urban 2/ Construction	Support 3/4/	Total	Plant	Support 3/4/	Total	Temporary	Permanent
1973									
1974									
1975									
1976									
1977									
1978	550	813	859	2,222				5,417	
1979	550	813	859	2,222				5,417	
1980	550	813	859	2,222				5,417	
1981					1,510	1,163	2,673		7,219

1/ Source: Bureau of Mines.

2/ Derived from value of labor for urban construction, see Table 2, footnote 1.

3/ Assumes 1.37 employed people per new household.

4/ Based on employment multiplier of 0.63 times temporary plant plus urban employment; Source: Same as footnote 5, but modified to reflect the experience that 1/4 of all construction support workers will not bring their families into the region.

5/ Based on employment multiplier of 0.77 times permanent plant employment, Source: Consulting Services Corporation, for the Public Land Law Review Commission, Study of Impact of Public Funds on Selected Regional Economics, April, 1969, p. 104.

6/ Based on a family size of 3.7 persons; Source: Bureau of Census data for Colorado, Utah, and Wyoming.

b. Expenditure Flows

During the three-year construction period, expenditures for plant equipment and construction materials will average $91 million per year (Table III-26). These materials and equipment are expected to be brought in from outside the county.

During the construction period construction and support salaries will total $23 million per year. When operation of the plant begins, salary payments to operating personnel and the associated urban support personnel will be $22 million per year (Table III- 27).

During the construction period Federal tax revenues, generated mainly from personal income tax will be about $3 million. State taxes will be $3.6 million per year mainly from the use tax on equipment and construction materials brought in from out-of-State.

When the plant is in operation Federal revenues will increase to $32 million per year, the increase being due to corporate income taxes and to royalty received on production. State revenues will be $5.3 million per year mainly from corporate income tax and the portion of royalty payments transferred to the State. Local taxes of $7.6 million per year will be collected as property taxes on the oil shale installation and on other residential and business properties (Table III-28).

Table III-26 Wyoming--Plant Equipment and Urban Materials 1/ Purchased

	Millions of Dollars		
	Plant equipment	Urban materials	Total
1973			
1974			
1975			
1976			
1977			
1978	71.3	19.5	90.8
1979	71.3	19.5	90.8
1980	71.3	19.5	90.8
1981			

1/ Urban construction is estimated at $45,000 capital cost per household for new residential, commercial, and community facilities. Of this total, $30,000 is allocated to materials and $15,000 to labor.

Table III-27 Wyoming Salaries and Distribution

	Millions of Dollars					
	Gross Salaries					Salaries spent 4/ within region
	Construction 1/ (Plant)	Construction 1/ (Urban)	Operating 2/	Urban 3/ support	Total	
1973						
1974						
1975						
1976						
1977						
1978	16.4	6.4			22.8	19.7
1979	16.4	6.4			22.8	19.7
1980	16.4	6.4			22.8	19.7
1981			13.1	8.7	21.8	21.8

1/ Plant and urban construction salaries assumed to be $12,000 per man year.

2/ Operating salaries assumed to range from $8,600 to $9,700 per man per year depending on the size of the plant.

3/ All support salaries were estimated at $7,500 per man-year.

4/ Assumes that one quarter of the construction workers will not bring their families into the region and that these workers will spend only one quarter of their salaries in the region.

Table III-28 Wyoming--Taxes and Public Revenues Generated by Oil Shale Development

	Millions of Dollars			
	Federal	State 1/	Local 1/	Total
1973				
1974				
1975				
1976				
1977				
1978	2.9	3.6		6.5
1979	2.9	3.6		6.5
1980	2.9	3.6		6.5
1981	31.8	5.3	7.6	44.7

1/ State and local tax rates applicable in Colorado were used to estimate regional tax revenues. Federal revenues are independent of State location of plant sites.

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9. "An Environmental Inventory of a Portion of Piceance Creek Basin in Rio Blanco County, Colorado," Environmental Resources Center, Colorado State University, December 1971.

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IV. MITIGATING MEASURES INCLUDED IN PROPOSED ACTION

A. General Measures

The probable environment impacts of the proposed prototype oil shale leasing program were assessed in the previous chapter. This chapter describes the type of measures which would be considered for adoption to prevent or to mitigate environmental damage if a decision is reached to implement the proposed prototype oil shale leasing program.

There are three paramount concerns involved in the development of the oil shale resources:

(1) human health, safety and welfare,

(2) mineral conservation, and

(3) environmental protection.

These concerns are reflected by specific provisions and stipulations in the lease proposed for the prototype oil shale leasing program. All three concerns are implemented by cross checks provided for in the lease, which are designed to detect and measure problems, require mitigating controls, and determine the effectiveness of such controls. The cross checking procedures envision a closed circuit system sensitive to deviation and responsive to change.

The comprehensive environmental review conducted by the Department in conjunction with State and local advisory staffs during 1970 and 1971 focused attention on the types of environmental hazards associated with the development of an oil shale industry. To minimize these hazards: (1) certain lands have been excluded from the proposed prototype leasing program; (2) provisions for protecting the environment would be incorporated into any coring permit or lease; and (3) general lease provisions would contain special stipulations applicable to the tracts selected for leasing, including monitoring requirements.

1. Exclusion of Lands

Oil shale occuring in lands that have a greater value for other uses, or that present associated environmental hazards which cannot reasonably be met or overcome at this time have been excluded from the prototype leasing program. The areas listed below, by State, have been excluded from the proposed prototype leasing program. Many of the excluded areas, although classified as oil shale lands, would not be affected in the forseeable future, since they do not contain oil shale of current economic interest.

Colorado - All national forest lands; Naval Oil Shale Reserves Numbers 1 and 3; fish and game experimental or management areas, including Little Hills Game Experiment Station, Little Snake, and Rio Blanco Lake.

1/ Naval Oil Shale Reserves can only be leased by agreement with the Department of the Navy.

Utah - Naval Oil Shale Reserve Number 2;[1] Desolation Canyon and that portion of the Green River designated as historical landmark; Sand Wash Historical Landmark, a Scenic Overlook on Book Cliffs Mountain Road, Watershed Study Area; a one-half township area which is a critical winter deer range; critical fish and game experimental or management areas, including Utah Herd No. 28A area, Indian Canyon, Starvation Reservoir, Blacktail, Red Creek, Golden Stairs, Avingtaquin Deer Winter Range, and Lake Canyon.

Wyoming - Lands adjacent to or within the Flaming Gorge National Recreation Area, and the Colorado River Storage Project; U.S. Bureau of Mines Oil Shale In Situ Experimental Sites; Seedskadee and Eden Reclamation Projects, including Seedskadee Wildlife Refuge and Migratory Bird Refuge, sodium (trona) mineral area, and a portion of phosphate reserve number 4.

1/ Naval Oil Shale Reserves can only be leased by agreement with the Department of the Navy.

Where oil and gas, trona, coal, or other mineral deposits are present on the public lands in the oil shale leasing areas, provisions would be incorporated in any lease agreement to provide, to the extent practicable, for compatible multiple development.

2. Core Drilling Provisions

General and special stipulations pertaining to environmental protection and control, similar to those planned for inclusion in any oil shale lease, have been incorporated into all coring permits to date, and will continue to be a part of any future permits to be issued by the Department. These include stipulations concerning field operations, restoration of land, and other provisions such as the protection of current surface uses or protection of fresh water aquifers that might be affected by drilling plan is required for approval by the Mining Supervisor. Such a plan specifies location, drilling method, size of casing, and safety precautions, and abandonment procedures, as well as a scheduled work performance. Designated Departmental field officials have access to all operation sites and operational data. Proper completion and abandonment is carried out under instructions furnished by the Mining Supervisor and is completed within one month after expiration of the permit. Failure to comply with the terms and conditions of the pertmit is cause for cancellation of the permit and forfeiture of the permit bond.

The permittee is required, among other things, to: (1) commence drilling operations within one year from the date of issuance of his permit; (2) conduct his operation in such a manner as (a) not to interfere with or endanger other land uses, and (b) to safeguard the water and other natural resource values; (3) comply with all Federal, State and local regulations or requirements pertaining to these operations, including 43 CFR Part 23 and 30 CFR 231; (4) post a $5,000 bond with the Department for each special land use permit issued to cover damages that may be caused to the environment or resources, either on-site or off-site, by construction, maintenance, and use of roads or trails, or by other activities conducted under the permit; and (5) post a $5,000 bond with the Department for each core hole to be drilled, to assure compliance with regulations (30 CFR Part 231) for drilling and abandonment operations.

3. Lease Provisions

The proposed lease with stipulations contains provisions for environmental controls which would require compliance with Federal and State laws. Chapter V, Volume III contains a copy of the proposed lease and stipulations for the prototype oil shale leasing program. Applicable Federal laws and regulations would include, but not be limited to, 43 CFR Part 23 and 30 CFR Part 231.

a. Standards

All applicable Federal and State standards for development on either public or private lands would have to be met in order to protect the quality of the air and water, including without limitation, to the extent applicable, the standards incorporated in Executive Order No. 11574 of December 23, 1970, Executive Order No. 11507, and Water Quality Improvement Act of 1970, (33 USC 1151-1175), 30 CFR 231 relating to control of surface subsidence above mined areas, and 43 CFR 23 which relates to revegetation of solid waste deposits retained on the surface. The environmental problems anticipated, however, would vary with the methods of mining and processing and with the characteristics of the area to be developed. Therefore, specific environmental safequards applicable to the prototype tracts would be incorporated into the leases to be issued, and their accompanying stipulations. These requirements are designed to provide assurance that the lessee would:

(1) control effluent gases and particulate matter to such a degree as to meet a Federal Standard of Performance as defined in Sections 109, 110, 111, 112, 113, and 115, of the Clean Air Act (42 USC 1857-1858a ET SEQ), as amended, and subsequent regulations appearing in the Federal Register as follows: 36 FR 816, April 30, 1971; 36 FR 15486, Aug. 14, 1971, 36 FR 24876, Dec. 23, 1971; 36 FR 23239, December 7, 1971, or to the extent consistent with Federal Law, meet standards established by the States:

Colorado: Air Pollution Control Act of 1970, Sec. 66-31-1 to 66-31-26, Colorado Revised statutes, 1963, as amended.

Utah: Utah Air Conservation Act, Sec. 26-24-1 to 26-24-18, Utah Code annotated, 1953, as amended.

Wyoming: Wyoming Air Quality Act of 1967 Sec. 35-487 to 35-502, Wyoming statutes 1957, C1967 as amended.

Each State has regulations implementing these statutes.

(2) control thermal pollution and maintain the quality of surface and subsurface waters in the area to comply with water quality standards established pursuant to the Federal Water Pollution Control Act., as amended; Executive Order No. 11507, State statutes, and those additional standards that may be required by the Department of the Interior.

These standards are designed to effectuate the mitigating measures described in the following discussion.

B. Measures Affecting Land Impact

There are two primary methods of oil shale extraction: (1) mining, either above ground or underground; and (2) in-situ. The environmental impact of oil shale extraction and surface processing on lands would result from any or all of the activities involved in the following:

(1) overburden disposal

(2) mined shale storage

(3) spent shale disposal

(4) site clearance

(5) surface subsidence

(6) waste-water disposal

Associated with these activities and influencing the impact are the related effects of dust, gases, water, and noise. Moderation of the effects of these activities can be achieved through (1) planning, (2) monitoring, (3) process modification, and (4) corrective action.

Special environmental stipulations will be made a part of each lease issued under the prototype program (see Volume III, Chapter V for a full copy of the lease and stipulations).

1. Spent-Shale Disposal

To the extent that both temporary and permanent surface disposal of spent shale would be necessary, the lessee would be required to compact and contour the disposal piles to avoid sliding, and to minimize their susceptibility to erosion and leaching. Natural water courses flowing either steadily or intermittently would be avoided, or would be diverted from the disposal piles. In addition, impounding dams and reservoirs would be required down stream from the disposal areas to trap water from rain or snow that might have become mineralized, or have picked up silt as the result of contact with the piles. In the case of permanent surface piles, the lessee would be required, in addition to taking the above precautions, to shape the piles ultimately to blend as well as possible with the surroundings, to take steps to expedite natural surface cementation processes, and to establish substantial vegetative cover of a permanent nature in keeping with that of the nearby surroundings. Similar requirements would be imposed in the case of open pit or strip mine areas as rapidly as feasible, once they had been filled or built up above the original surface elevation with spent shale and/or other solid material.

At such time as areas that had been cleared for either above-ground or in situ plants or related facilities were to be abandoned the lessee would be required to restore the affected areas to a usable and productive condition consistent with or equal to pre-existing land uses in the area and compatible with existing adjacent undistrubed natural areas.

2. Dust, Gas, Water and Noise Controls

Pertinent precautionary measures would be required of the lessee to avoid land or vegetation damage from process-related dusts, gases, and contaminated water. Airborne dusts from processing sources would be expected primarily from oil shale crushing and conveying operations prior to retorting, and in movement of spent shale to disposal areas. Migration of such dusts would be controlled by the use of dust collectors at conveyor transfer points and on crushing and screening equipment. Conveyors would be hooded to minimize dust loss to the air. Optionally, in the case of spent shale disposal the lessee could elect to moisten or slurry the material as a part of the disposal procedure, which would incidentally eliminate any dusting problem. Dusts from any surface mining operations would not be as completely controllable, but would be minimized by the use of water sprays.

Conformance with air pollution regulations (Section IV-D) would obviate any significant danger of damage to vegetation over the lands in the vicinity of the shale operations.

Water produced incidentally to plant operations would be impounded, and in all probability either treated for use in the plant or utilized in spent shale disposal operations. In any event, release of untreated water to the surrounding area would be banned under the terms of leases, essentially eliminating any possibility of land damage from this source. In the event that large quantities of high quality and/or treated waters are obtained from mine or pit dewatering were discharged to small drainage ways, erosion would be accelerated; however, water of acceptable quality for discharge into any part of the Colorado river system would be a valuable commodity and would be used.

3. Mined Shale Storage

A mined shale stockpile will have to be maintained to provide for work stoppage and other related problems. The size of the mined shale stockpile is directly related to the plant size. Because of the complexity of plant operations and volumes of materials handled, one-week standby of material would probably be the extent of the mined shale stockpile.

Mitigating measures would in many respects be similar to those applied to spent shale disposal. Every effort would be made to place the storage site in such an area as not to detract from the aesthetics of the area. When plant operations were complete, any remaining mined shale could be treated in the same manner as overburden, and either placed back in the pit or underground, depending upon the mining method.

C. Measures Affecting Water Resources Impacts

Protection of existing water resources will require a much better understanding of their occurrence before mitigating actions can be instituted. Evaluation of data collected prior to mining and monitoring of the resources after mining has begun will be necessary to assure that proper actions are taken and that they are successful. However, the program cannot anticipate what might happen on private lands at some future time. On public lands under the Department of the Interior's jurisdiction, the following measures will lead to a better evaluation of the water resources, will document causes and effects, and will enable corrective actions to be taken that will mitigate the impact on water resources:

1. Collection of field data needed to construct and calibrate detailed mathematical models of ground-water movement at each mining site;

2. Description of the quality of groundwater and its relationship tp permeability distribution, including water head and quality distribution under development and operating conditions, and their changes with time;

3. Monitoring of head and quality distribution in aquifers before, during, and following operations on the lease.

4. Determination of the quality of water that can be used for various processes and design plant system for best use.

5. Determination of the quality of effluent from various parts of the plant and the design for use, disposal, or treatment of the waters prior to operations.

6. Monitoring stream quality (chemical and sediment) and discharge at strategic points within the region, in order to detect changes caused by oil shale operations and to take corrective action. Background data will be collected as early as possible, in order to serve as a guide as to whether changes are natural or man-made.

7. Control of erosion during construction by mulching, revegetation, and other methods.

8. Construction of sediment traps of adequate size for construction sites, overburden disposal sites, crushed shale piles, and spent shale disposal piles.

9. Monitoring chemical quality of water in sediment traps below spent shale disposal sites, and monitoring aquifers beneath and down gradient from spent shale disposal sites and evaporation ponds.

10. Construction of adequate and fail-safe facilities and regulations to prevent or waste water spillage.

11. Treatment of surface of spent shale disposal piles to prevent erosion by water or wind.

12. Monitoring the chemical quality of water in vicinity of backfilled mines and subsurface injection sites.

13. Continued research on effects of leaching from spent shale, both surface and subsurface disposal, on quality of water.

14. Treatment and monitoring of all sanitary effluent and process waste water before discharge to streams, in order to meet Federal and State standards.

15. Drilling, testing, and evaluation of possible subsurface sites for waste injection.

16. Development of a water plan to consider regional, municipal and industrial water supply and waste disposal.

D. Measure Affecting Air Quality and Noise Impacts

1. Air Quality

a. Plant Location

The location of the retorting-processing portions of the plant coul be a determining factor in the local impact of air pollution. Since portions of the Piecance Basin and eastern Utah frequently experience atomspheric temperature inversions, it is clear that source emissions must be controlled that pollutants do not accumulate under inversions conditions. Where ever feasible, processing facilities should be located on upland surfaces rather than in valleys and canyons.

b. Control Methods

(1) Particulates-Potential dust from surface waste disposal piles, mentioned previously, would be prevented by moistening the material and using disposal and revegetation techniques already under development in field tests. If residue shale were transported in dry form, covered conveyors would be required. If the lesse returns spent shale to the underground mining operations, it is

expected that a majority (up to 80%) of the waste could eventually be returned to the mine, thus reducing potential dust producing surface piles. The shale crushing operation would require enclosed crushing and conveyor facilities wherever possible, and protection of the piles of crushed shale.

2. Process Stack Gases

Air pollution control devices and methods envisioned for a prototype oil shale complex would normally incorporate the following technological controls:

<u>Raw Shale Transport and Storage</u>

Water sprays
Dust collection
Conveyor covers
Surge bin covers
Storage pile covers

<u>Crushing</u>

Enclosure
Water sprays
Dust collection
Conveyor covers

<u>Retorting</u>

Dust collection - raw shale feeders, preheat system vents, ball system vents, retort residue cooling and wetting
Dust cyclones
Dust scrubbers
Dust scrubber slime system

<u>Pre-Refining</u>

Process fuel sulfur removal
Storage tank covers and floating roofs

Processed Shale Disposal

Conveyor covers
Wetting water
Compaction equipment
Topping
Revegetation
Mine disposal

3. Noise

Noise would be controlled by the installation of the latest noise abatement techniques in equipment and processing. Monitoring and objective noise control efforts would have to be continuous to maintain an acceptable noise level.

E. Measures Affecting Fish and Wildlife Impacts

The Department, through the Bureau af Sport Fisheries and Wildlife, and in cooperation with the State Divisions of Game, Fish and Parks, universities, and various other private or public organizations would work cooperatively with representatives of the oil shale industry to minimize the impacts of oil shale development upon fish and wildlife resources.

The types of measures which would be taken to prevent or mitigate environmental damage to fish and wildlife values are described in more specific detail for the individual lease tracts in Chapter V of Volume III.

Land restoration objectives would be primarily aimed at replacement of winter-range food and cover requirements for big game species, including mule deer and antelope. Land restoration plans would also give full consideration to the year-long habitat needs of existing wildlife species when rehabilitation and management decisions are made.

Specifically, pertinent wildlife-oriented research and investigations would be required upon the initiation of oil shale operations, ancillary development, and resulting population pressures, with particular reference to specific new problem encountered during on-going monitoring activities.

F. Measures Affecting Grazing and Agricultural Impacts

Timely notice of a proposed oil shale lease will be given to all affected grazers to meet the requirements of the regulations and to allow time for the necessary adjustment in livestock operations.

Disturbed surface areas used for grazing would be backfilled and revegetated to, in part, restore grazing capacity for domestic livestock. Accepted standard revegetation practices will be used to restore a suitable plant cover. Revegetation for grazing would include seeding and planting which would be repeated if prior attempts to revegetate are unsuccessful.

Range livestock facilities will be protected by requiring the oil shale lessee to do the following:

1. Fence appropriate mining, deposit and plant site areas to prevent the loss of livestock;

2. Replace any needed fences destroyed in the program operations;

3. Develop alternate watering sites lost or destroyed during program operations; and

4. Provide cattleguards on access routes used in the program operations.

G. Measures Affecting Recreation, Aesthetics, and Cultural Values

Measures which would lessen or compensate for the detrimental effects of the oil shale development on recreational, aesthetic and cultural values resulting from lease operations could include the following:

(1) Reduction of the symmetric type of landscape, created by building, powerlines, road, and trails, by tailoring their design and location to blend harmoniously with the natural surroundings.

(2) Contouring of waste disposal areas so as to blend harmoniously with existing land forms and revegetate such areas with adaptable plants.

(3) Establishment of huntable population of small game animals and birds, where feasible, to compensate for reduction of mule deer numbers.

(4) Proceeding with caution in exploratory and development operations and providing trained archeologic monitoring so that

archeologic values can be promptly identified; prompt notification of the Secretary of the Interior when objects of possible archeological significance are discovered.

H. Measures Affecting Impacts on Economics and Social Environment

Many of the potential adverse effects of urbanization could be mitigated by advance planning now underway by the following groups. In Colorado, Rio Blanco, Garfield, and Mesa Counties each have planning commissions. In addition, these three counties have joined together to form an Oil Shale Regional Planning Commission. In Utah, the City of Vernal has a planning commission which has developed a planning and zoning program encompassing all of Uintah County. In Wyoming the Sweetwater County Planning Commission has adopted a zoning resolution which will enable it to establish guidelines for growth.

I. Measures Affecting Safety and Health

Plans for development would have to be approved for any new mine on public or private lands as required by applicable Federal and State laws, and the mine would be inspected to insure compliance with the approved plan and with all mine health and safety regulations. Also, new and more demanding metal and non-metallic mine health and safety standards, as contained in 30 CFR Parts 55, 56, and 57, will apply.

V. ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED

Plant construction, operations, and associated activities would lead to some effects which are both adverse and unavoidable. These unavoidable adverse effects are categorized and examined in the following sections.

A. Effects on Land

1. Topography

The development of an oil shale industry would require roads, mining, plant sites, waste-disposal areas, utility and pipeline corridors, and associated services during the productive life of a lease. These activities would change the existing pattern of land use and alter the existing topography. Such disturbances would unavoidable exist throughout the life of operations, but would be temporary in the sense that restoration of surfaces to original or improved condition would be required before site abandonment. The cumulative land under development or otherwise not usable was shown to reach a plateau of about 20,000 acres for a 1 million barrel per day cumulative production. Land effects will vary depending on the mining and processing systems that may be used.

Waste disposal areas are generally considered to be in canyon and gully areas which would gradually be converted into flatter areas. Contouring and revegetation would restore scenic attractiveness and probably reduce erosion from the area.

These changes in topography would alter the appearance of the land and would affect natural vegetative cover until re-vegetation operations began. These changes would be adverse, in the sense that the area's present topography and semi-wilderness character would be altered. The degree to which these topographical changes are adverse, however, is a value judgement difficult to quantify. With proper restoration methods the scenic impact could be kept within acceptable limits. The actual impact would depend on the specific sites that may be chosen for disposal.

2. Use Patterns

There parts of any lease site areas are now used for livestock grazing. 1/ agriculture, wildlife habitat, or recreation, some unavoidable changes in land use patterns would result.

The total impact would be significant in local areas but slight for the region as a whole because the percentage of the region's total surface area affected by development (including urbanization) would be small. However, some local dislocations would unavoidably occur. The extent to which any changes in land use patterns would be adverse are discussed in the sections to follow, together with potential adverse effects on water and air resources.

1/ The impact on wildlife is considered in Section D of this chapter.

B. Effects on Water Resources

In order to insure dependable supplies of water from the Colorado River or its tributaries, dams and reservoirs must be constructed, or water must be purchased from existing reservoirs.

The water diverted for all uses would have an unavoidable impact on regional water supplies, because any storage, diversion and net consumption of existing water resources would deplete natural streamflow. This in turn would increase the salinity concentration of the Colorado River at Hoover Dam from 6 to 10 mg/l; a maximum of 1.4 percent for the full 1 million barrel per day industry. Other salinity influences could occur from accidental releases, surface water runoff, and water table depression.

During the period between disturbance of the surface and revegetation, high intensity rains could cause accelerated soil erosion and channel cutting and could increase sedimentation in the stream beds. The cumulative impact of this over time would be quantifiable by sediment measurements of the major rivers. Water discharged into the streams could add to the erosion factor and sediment load.

Drainage courses and channels would probably be diverted because of mine facilities and waste disposal areas. The quantity of impact depends upon the type and intensity of mining operations and control measures used.

As oil shale development proceeds, increased population in all areas would put a greatly increased sanituary waster load on regional water supplies. Even with the best of treatment and disposal facilities this effect cannot be fully mitigated, and in this sense is adverse.

The disturbance of ground water by mining operations, or by water used to return spent shale underground for disposal, could have an adverse effect on subsurface water quality, ground water movement, water levels, spring flow, and streamflow. Knowledge of aquifer characteristics, head relations, and chemical quality distribution in the aquifers in much of the region is inadequate and the extent of this impact cannot be predicted. Specific information developed during core drilling and ongoing research might reduce the risk of adverse impacts on aquifers. Close monitoring of the quality of ground water, and prompt action to change operations detrimental to water quality would help mitigate adverse effects.

C. Effects on Air Quality and Noise Level

1. Air Quality

Proper techniques already exist to adequately control emissions, including particulates, sulfur oxides, and nitrogen oxides potentially present in various fuel gases, and the dusts produced in mining and shale disposal.

It is expected that all applicable Federal and State criteria on acceptable air quality standards could be met. Residual concentrations of sulfur would total some 228 to 340 tons per day and dioxide would total 84 to 116 tons per day. Solid particulates in gaseous discharges to the atmosphere would be small, but unavoidable for the program at the present state of technology. New control techniques now being developed for other industrial operations could be incorporated into this industry, which is at least 2, and possible 4 years from construction. Some local problems with temperature inversion may be experienced, the significance of which cannot now be established. The long term effect of industrialization would result in a decline in general air quality of the region.

2. Noise Level

The local noise level at and near the selected sites is expected to increase, due to the minng, retorting, and other processing operations. This is an unavoidable adverse consequence of the increased industrial activity in a region which is presently predominantly a semi-wilderness, and can be only partially mitigated by noise abatement devices.

D. Fish and Wildlife Changes

1. Impacts of Oil Shale Operations

Construction and operation would have varying degrees of direct and indirect impacts upon fish and wildlife and their habitat in the immediate vicinity of the plants and along their appurtenant roads, surface facilities, and pipelines. Noise and associated human activities accompanying construction and operation would have a new effect of stress and disturbance on normal behavior and activity patterns of wildlife. Depending upon lease site characteristics, species which would be affected by such disturbances include mountain lion, bear, elk, mule deer, antelope, bob cats, sage grouse, blue grouse, and migratory birds. Animal species such as mountain lions, elk, and peregrine and prairie falcons, would be intolerant and areas of up 20,000 acres per year would be completely lost to them as habitat.

Air strips and increases in air traffic would provide some source of aerial harassment of mule deer, wild horses, and other big game, the extent of which would be dependent upon the number and location of air strips and the volume of air traffic which would be involved.

Wildlife food and cover values of lands used for mining, pipeline and road construction, buildings, etc., would be at least temporarily lost. Permanence of such losses would be dependent upon the time required for and success of re-establishing useful wildlife food and cover. Such habitat loss of wildlife production capacity for the developed acres would in turn be reflected in lower populations of animals. For example, removal of critical winter browse would result in a corresponding reduction in mule deer numbers.

Oil shale-related drying of surface water features, such as springs, seeps, and small streams, would change the natural plant-animal complex associated with each particular water feature, including the related distribution of game, wild horses and cattle.

Coverage of roadside vegetation with vehicle-cause dust would constitute a minor but chronic, problem, since such vegetation would lose its wildlife food value until washed off by subsequent rains.

Unpredicted or uncontrollable changes in the quality of local surface or ground water would result in accompanying impacts on aquatic fish and wildlife populations and their habitat. In the event that sediment, leached substance, saline ground waters and/or toxic materials were released to surface waters as a result of oil shale operations, adverse impacts would be imparted to aquatic plants and animals. Unless carefully controlled such discharges would have adverse effects on aquatic habitat of the Colorado, Green and White Rivers and other exposed water areas. Adverse impacts would also be expected in exposed aquatic habitat in the form of lowered biological productivity, physical covering of fish spawing and nursery areas.

The product oil handling, storage, and transmission system, including feeder pipelines, would exhibit some small losses of oil. Spills would follow natural drainage features and released oil would result in mortality to trees, shrubs, and other vegetation with which it came into contact. Adverse effects would also occur to birds, some species of both land and water mammals, and fish and other aquatic organisms with which the oil came into contact.

2. Ancillary Urbanization and Human Pressures

Oil shale-related urbanization would also result in some regional adverse impacts upon fish and wildlife and their habitat. Facilitated access and increasing human habitation and activities would result in a region-wide disturbance and stress on wildlife populatons. Reductions in surface water quality would occur near population centers, as a result of sewage, toxic substances and siltation and such reductions would have adverse impact upon aquatic organisms and their habitat. Some wildlife habitat would be consumed for buildings, roads, parking lots, etc. Additional wind and water erosion would occur. Increased ground vehicle traffic would result in more frequent road kills of deer and other game.

Increased hunting pressure would cause localized adverse impacts upon wildlife through reduction of populations of some species. Increased harvest of mule deer, elk, moose and antelope would require regulation in order to avoid undesirable downward population trends. Region-wide increased hunting pressure would have the most potential for further reductions in very low abundance species, such as brown bear and cougar.

A predictable decrease in the quality of both angling and hunting experience would occur wherever intensified use resulted in fewer and/or smaller fish and game and the physical presence of more hunters or fishermen. One significant effect of a regional oil shale industry would be the net loss of semi- remote hunting and fishing qualities, caused by visual and audio effects of road, vehicular traffic, etc.

Both development and associated urbanization would contribute to those factors which have resulted in the rare and endangered status of several species. If impoundments were constructed on the fast water streams of the humpback chub and Colorado River squaw fish, the presently limited habitat of these species would be further reduced. Adverse effects of herbicides and pesticides introduced to the food chain through localized pest or vegetation control programs would occur but would be expected to be very minor. Such side-effects would be dependent upon the volume and types of chemicals use.

E. Effects on Grazing

A 1 million barrel per day oil shale industry would affect annually about 20,000 acres undergoing mining disposal, and restoration, 15,000 to 20,000 acres for human use (residential, etc.) and 1700 to 2000 acres for utilities. Based on 30 years of operation, and 20,000 acres affected, these activities would result in a temporary loss of 42 AUM's per year and a loss for the duration of 172 AUM's per year. This is assuming that land used for off-site requirements is largely unavailable for grazing or unsuitable. However, the pipeline corridors are unavailable only temporarily. After revegetation the forage production is normally equal or better than before. On the other hand, the changes in life styles or other factors could lead some present livestock operators to reduce ranching activities or cease entirely. While this might not affect actual forage production, it would reduce utlization and effective production of beef.

F. Effects on Aesthetics, Recreation Patterns, and Cultural Values

The new roads, trails, plant sites, waste disposal areas, utility and pipeline corridors which would be part of the prototype oil shale industry would affect the appearance of the present landscape. This is also true of the mining operations, whether underground or on the surface, and applies to in-situ processing as well. The extent of these changes has been reviewed above. The extent to which such alternations in topography could be considered aesthetically adverse is a matter of personal judgement which is difficult to assess quantitatively.

Vegetative rehabilitation success is dependent upon soil quality, water availability, nutrients, and plant vigor. Rarely is the re-established vegetation on disturbed sites as productive or as suitable to wildlife species as the endemic food and cover plants, especially the aspect related to cover and seasonal nutrituion values; therefore, long-term reduction in value of the wildlife habitat, and attending recreational opportunity, on all seriously disturbed development areas could be expected. Also during the period between disturbance of the surface and revegetation high density rains could cause accelerated soil erosion and channel cutting, and could produce increased sedimentation in stream beds, especially those of the free flowing Piceance Creek and White River. Such siltation could have an adverse effect on fishing opportunities and other associated water oriented recreation activities.

Although there are no known historical or archaeological sites on any of the selected tracts, it is a reasonable assumption that the sites or the general area was formerly inhabited by nomadic, hunting, Indian tribes. Any disturbance of the surface, especially an open pit mining operation, could possible disturb some unknown historic archaeological site or artifacts. However, such activities would also increase the probability that such items would be located.

G. Effects on Economic and Social Environment

The increased urbanization of a region which is primarily rural, would be an unavoidable consequence of the oil shale development. Since the benefits and costs of urbanized life versus rural life are a matter of personal value judgement, it is impossible to assess the degree to which the social environmental impact would be detrimental. To the degree that urbanization provides diversity of opportunity and choice, the new social changes could be considered beneficial.

VI. RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The prototype oil shale leasing program would inescapably involve commitment of a portion of the region's shale, land, water, and air resources, other mineral resources, and fish and wildlife. The extent of these commitments and an assessment of their environmental impacts have been previously detailed. However, the relationship between this proposed use of the environment and the maintenance and enhancement of its long-term productivity are examined below.

A. Energy and Mineral Resources Gain

In Volume II of this analysis, it was shown that the domestic supply of crude petroleum by 1985 is expected to be 10.11 million barrels per day, including oil from Northern Alaska. The growth of a shale oil industry to the 1 million barrel per day level would therefore increase domestic oil supplies by 10 percent and reduce the Nation's dependence on foreign sources by 1 million daily barrels.

The establishment of an oil shale industry of this magnitude would also tend to maintain an upper limit on crude oil prices.

Beyond the energy gains that could be achieved, certain oil shales on the Colorado tracts are known to be in or associated with dawsonite, an aluminum-bearing mineral, and nahcolite, a natural form of sodium bicarbonated.

At the present time, the technology and economics are not firmly established for processing these shales for recovery of alumina (which then could be converted to aluminum) and soda ash or other related "sodium" products. However, the possibility exists that development of the Colorado leases would lead to feasible processes for such recovery. Development of an alumina recovery process, in particular, could be of great National benefit since the United States now is almost totally dependent upon foreign sources of aluminum ores. The nahcolite values do not currently represent as important a national need; however, these too could prove of potential benefit as treating agents for reduction of sulfur oxides and other noxious acid-type components of industrial stack gases, if laboratory tests are confirmed on a commercial scale.

B. Improvements In Technology

Oil shale development and continued research could be expected to result in technological advances in practically all direct phases of operations and in the area of environmental control. Such advances could significantly help maintain and enhance long-term minerals productivity of the oil-shale region.

Increased efficiency in both mining and processing would result in increasingly effective utilization of the oil-shale resource itself. Innovative mining systems could result in higher percentages of extraction than now seem feasible, thus conserving the resource and decreasing the area required for a given rate of production. Increased yields in retorting and refining would decrease the mining load commensurately, also tending to decrease the mine and spent-shale disposal areas required for given oil output rates.

Improvements could be anticipated in techniques of promoting vegetation growth over spent-shale disposal areas, both in minimizing the time required to achieve substantial, permanent, growth, and in broadening the range of possibilities of the types of vegetation possible. Advances also could be anticipated to control and treat if necessary mine and produced process waters for in plant use. Maximum reuse of such water would lower the demand on fresh water from the Colorado River system.

C. Water Resources

Consumption of water by an oil shale industry would constitute a net depletion of available regional water resources, but its use measured in terms of the utilization of a portion of the oil shale resources is beneficial. Given the controls envisioned for water use, degradation in regional surface water quality would be slight, but the long term effect of industrialization could lead to a decline in water quality. The salinity concentration of the Colorado River at Hoover Dam would be increased about 1.5 percent.

Ground-water pumping for oil shale industrial supply or mine dewatering would reduce the amount of water that would need to be diverted. However, this would lower aquifer pressure and water levels, thereby decreasing the flow of springs presently used for irrigation and stock watering. In addition, saline water may move into aquifers that now are fresh, reducing the future quality of water available for human and agricultural use.

D. Productivity of Fish and Wildlife Resources

A regional oil shale industry would involve a broad group of environmental impacts upon fish and wildlife and their habitat. These impacts have already been discussed in Chapter III. Although occurring principally during tract development and oil production, some of these impacts would extend beyond the expected longevity of production. For example, permanent regional population increases would result in a continueing use of regional fish and wildlife resources, even after oil production has ceased.

Development of a regional oil shale industry would cause an aggregate of adverse impacts upon fish and wildlife resources, both within the vicinity of each development tract and, through ancillary human pressures, across the oil shale region as a whole. Because of this aggregate and the fact that the industry would have very few features that would enhance productivity of biotic resources, it is concluded that the expected short-term uses of oil shale would to some extent adversely affect the long-term productivity of the region's wildlife and fish resources.

E. Changes in Recreation Patterns and Aesthetics

Oil shale development would result in localized as well as Basin and Regional changes in recreation and aesthetic resources.

The expected development in the three-State-region, together with the related new urban service and utility corridors, would involve a limited percentage of recreation lands. However, the sum total anticipated will exert a considerable impact on the existing environment beyond the boundaries of the development itself.

Existing land use programs, on and in the vicinity of the projects involve coordinated management of urban as well as the natural resources (soil, water, mineral, forest and wildlife) to provide for quality recreational opportunities. The objective would be to maintain existing recreation resources with as little disturbance as possible; but at the same time to introduce the change towards needed urban oriented recreation facilities, such as: golf courses, reservoirs, play grounds, swimming pools, etc. Therefore, the optimum relationship between program implementation and maintenance of long-term recreation resources would involve cooperation among the government, industrial and private sector, in anticipation of adverse impacts, implementation of the much needed research, and the development of the management programs needed to minimize or mitigate the adverse impacts. However, any change in the primitive quality of the region due to development would adversely affect its present character.

F. Economic Development of Adjacent Regions

Over the long-term, the economy of the oil shale region, the States involved, and the Nation could be enhanced by prototype development. The projected increases in employment, capital inflow, personal income, and tax revenues that would occur have been quantitatively evaluated in Chapter III. These increases could provide incentives for greater upgrading of the private sector of the economy than has been projected.

An improvement of community facilities should be possible as a result of the expanded tax base. This, in turn, could act as an effective catalyst at State, county, and local levels for coordinated and comprehensive planning to ensure orderly growth as the prototype program develops. Both existing and new communities would benefit from better or new school systems, libraries, hospitals, parks, municipal water and sewage systems, streets, and airports.

Community life in the region would change. The rural character of the region would give way to increased urbanization, and employment in industrial occupations would take place. Any change in the rural nature of the region would be both adverse and beneficial. Recreational activities would increase with population growth and the increased demand should result in development of new recreational facilities. The introduction of increased noise levels in the primitive areas of the region would be generally considered adverse.

It is difficult to make a value judgment on these social changes, and hence to determine whether a net enhancement in the lives of the area's residents would result from oil shale development. This is a question of personal assessment and opinion and must be balanced against the effect on the natural resources (water, air, land, wildlife and vegetation) of the area whose long-term productivity would decline. In an overall sense, the population would be regarded by most as a beneficial effect of the development.

VII. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The purpose of this chapter is to examine those resources which would be consumed and those that would be altered irreversibly and irretrievably by the proposed prototype oil shale leasing program. Such commitments would include: the consumption of certain mineral resources; changes in the relief of the terrain and in land use patterns; modification of wildlife habitat; new directions in the patterns of community activities; and changes in existing recreation, aesthetic and cultural values.

A. Consumption of Mineral Resources

The principal mineral resources consumed by the proposed prototype program would be the shale oil and associated products, and the water and other resources required in their production.

By the year 1985, total production may be expected to rise gradually to 1,000,000 barrels per day, a cumulative total of approximately 365 million barrels of shale oil and shale oil products would be produced annually for consumption. To achieve such an output, 425 million tons of raw shale would have been processed, 80 million tons of useful products removed, and up to 340 million tons of processed spent shale produced. Each year, from 116,000 to 164,000 acre-feet of water would be consumed for industrial and domestic use and some natural gas may be used for plant fuel.[1/] Saline minerals may also have been removed.[1/]

1/ The quantities of natural gas and saline minerals have not been estimated, since these would be dependent upon the type of processing employed.

During twenty years of continuous operation, therefore, some 8.5 billion tons of oil shale resource would be irreversibly and irretrievably "consumed."

Ultimate recovery of oil shale mined underground, by room and pillar methods, should approximate 50 to 65 percent of the leased deposit without causing undue surface subsidence or damage. That resource left in place as barriers (e.g. manways, main and secondary entries, haulageways, airways, bleeder entries, shafts, slopes, room necks, and rooms) is necessary to protect the workmen, deposit, and the overlying surface lands. Such material is unavoidably lost; however, this loss can be minimized if sound mining practices are adhered to and safe extraction procedures are followed.

Theoretically, mining by surface or open pit methods should recover nearly 100 percent of the available material. In practice, this is not the case, since ore must be left as a barrier to protect lease boundaries, and benching is necessary to gain entry and exit to and from the deposit. Therefore, it must be assumed that between 10 to 20 percent of the oil shales would be lost to recovery and utilization.

In situ processing will probably result in only 50 percent recovery of the in-place resource. The remainder will be irretrievably lost.

B. Changes in Land Use Patterns

1. Industrialization

Oil shale leasing development through 1985 is not expected to support new industrial activities within the oil shale region. Equipment and supplies both for these oil shale installations and for the maintenance of the increased population are expected to be brought in from outside the region. A concentration of plants and of population in one locality, however, would probably support the manufacturing of some locally consumed products. Such industrialization would be expected to take place in urban areas most accessible to the largest concentration of oil shale plants.

2. Topographic Changes

Topographic changes fall into three categories. Those associated with urban development, those associated with utility corridors and the expansion of the roadway system between urban areas and the plant sites, and those associated with the development of the plant sites and mining areas themselves.

The area of land transformed from rural to urban use will be directly proportional to the new population of the area which in turn will be almost proportional to shale oil productive capacity. For the 47,000 new population associated with 400,000 barrels per day capacity by 1981 and assuming a population density of 5 per acre, 9,400 acres of land would be urbanized. For all practical purposes, this area would essentially constitute an irreversible commitment of this land.

New roads and utility corridors to the six plant sites would occupy about 2,000 acres of land. The land occupied by roads to plants expected to be built on private lands will depend upon the locations of those plants which are presently unknown.

Topographic changes at the plant site will be caused by underground mine openings, surface mine excavations, processed shale disposal areas and plant facilities. For a 1,000,000 bbl day shale oil production operation, the total estimated land disturbed is about 50,000 acres. Spent shale could, in some underground mining operations, be replaced in the mine, providing permanent support for those excavations. Underground mine openings could be permanently sealed at the end of operations.

Surface mining and surface disposal of processed shale would cause permanent changes in topography. In each case the surface would be recontoured and revegetated to provide a stable surface. Soils that may be lost to erosion and to back filling would, however, be irreversably lost.

3. Modification of Fish and Wildlife Habitat

Establishment and operation of a regional oil shale industry would result in two general sources of irreversible and irretrievable commitments of fish and wildlife and their habitat. The first source would be those commitments resulting from construction and operation activities at and in the vicinity of oil shale installations; while the second would be accompanying regional urban development.

Irreversible and irretrievable commitment of fish and wildlife resources resulting from both sources would include: permanent losses of natural surface water features, such as springs and seeps; and their associated plant and animal complexes; effective loss of fish and wildlife production on and near the actual oil shale tract and at associated urban development areas; and a net loss of remote country hunting and fishing values. Regional oil shale urban development also has the potential to adversely affect existing rare and endangered species populations of the region.

C. Commitment of Water Resources

From 80,000 to 125,000 acre-feet per year of surface or undergound water could be used to support the water requirements of 1,000,000 barrel per day industry and supporting population. Part of this water would be diverted from the Colorado, White and Green Rivers and would not be available for other, but as yet unspecified, water needs.

Pumping to dewater mine areas in Colorado may result in establishing a cone of depression, which may in turn lead to encroachment of highly mineralized ground water into the area under development. Dewatering the leached zone in the Piceance Creek Basin may lead to compaction of the Green River Formation and possible ultimately cause local land subsidence, decrease in stream flow, and drying up of springs with a consequent adverse effect on animals and plants.

D. Changes in Socio-Economic Patterns

The increased economic growth resulting from the initiation of the prototype program would significantly alter existing social structures and institutions. The evolution of an agricultural society to an industrialized one would be largely irreverisible and may produce intermediate community instability. Strains of rapid population influx could result in a dichotomy between the established and new inhabitants of the region. However, the intense industrialization of the affected areas, with consequent increased employment, greater capital flow, and broadening of the tax base would benefit the total social environment by upgrading existing community amenities, such as public schools, hospitals, libraries, and water and sewage systems. Existing pre-industrial life styles with their emphasis on recreational activities and subsistence economic patterns eventually would be exchanged for an urbanized way of life. In the long run, the societal impact could be a more broadly based stability of rural aesthetics intertwined with urban cultural amenities. The new tax income received by all segments of government (Federal, State, and local) would be a welcome addition to the economy at all levels.

E. Changes in Recreation, Aesthetic and Cultural Values

The proposed oil shale projects would constitute the creation of an industrial complex upon a relatively semi-primitive, remote, natural environment. Certain scenic landscapes with their attending vegetation, water, and wildlife habitat which provide recreational opportunities would be lost for decades.

CONSULTATION AND COORDINATION IN DEVELOPING THE PROPOSAL AND IN THE PREPARATION OF THE STATEMENT

The Departmental activities related to the proposed prototype oil shale leasing program have required nearly three years of study, planning and consultation to develop the program and to obtain the data included in the Department's Draft Environmental Impact Statement. There is shown below a summary of major past activities, and also the anticipated future planning schedule. Public hearings on the draft statement will be held prior to a final determination concerning program implementaing.

A. Past Planning Activities

October 1969 - An oil shale study was initiated by the Assistant Secretary--Mineral Resources and the Assistant Secretary--Public Land Management.

October-December 1969 - Review of Mineral Leasing Act and previous Departmental efforts to lease oil shale resources in public lands.

December 1969 - Oil Shale Task Force formally established to draft a prototype oil shale leasing program proposal and to implement a program if approved.

May 1970 - Proposed program presented to the Secretary of the Interior, who directed that additional environmental analysis be made prior to program implementation.

May-June 1970 - The Governors of Colorado, Wyoming, and Utah formed State Committees to study the environmental impact and related costs for appropriate environmental controls.

June 1970 - Public meetings conducted in each State on the proposed prototype leasing program.

August 1970 - Officials of private, State, and Federal agencies conducted a week-long field survey of sites typical of those that may be developed.

August 1970 - December 1972 - In the three-state area, 25 public oil shale meetings have been held.

February 1971 - State Governors formally transmitted to the Secretary of the Interior an evaluation of the environmental impact of oil shale development as related to the resources in their States.

March-June 1971 - Interior's preliminary draft environmental statement and program statement for a Prototype oil shale Leasing Program were prepared, and submitted for public inspection.

June 1971 - Informational core drilling authorized and carried out on public oil shale lands in Colorado, Utah, and Wyoming. Over $2 million spent by private firms on 16 holes aggreating 24,647 feet of drilling for exploring and evaluating Federal lands prior to submitting nominations for leases by February 1, 1972. Surface area was restored and the entire operation was conducted without significant environmental impact.

September 1971 - Board of County Commissioners of Garfield, Rio Blanco, Mesa counties, Colorado create an Oil Shale Regional Planning Commission.

November 1971 - Department of Interior published notice of call for nominations of areas for oil shale leasing. Fifteen companies submitted 17 nominations on 13 separate tracts in Utah, 1 nomination on 1 tract in Wyoming. The 23 industry nominations on 18 separate tracts in the 3 states were supplemented by 2 additional tracts nominated by the Governor of Wyoming.

January 31, 1972 - Lease nominations were closed.

February-April 1972 - The nominated tracts were reviewed by a selection committee of Federal and State experts, in order to recommend a total of six tracts, two in each State, for competitive-bid leasing. The six recommended tracts were further reviewed by the Department of the Interior, and by representatives of the Governor's Task Force in each of the three States, and the final selections announced on April 25, 1972.

April-September 1972 - Revised draft environmental statement was prepared by Interior and published in three volumes: (1) A regional overview of the expected environmental impact of a prototype oil shale leasing program and the projected impact of a mature 1 million barrel per day shale oil industry; (2) a discussion of other energy sources which may be considered as alternatives to the development of oil shale; and (3) an analysis of the impact of development of six specific proposed lease tracts.

B. Agency Participation

Personnel from the following Federal and Non-Federal organizations have participated in the environmental analysis of the program and preparation of the draft Statement, either through direct participation, as consultants, or in reviewer or observer capacities.

Federal Agencies

Department of Interior

Oil Shale Task Force - Staff selected from the Bureau of Mines, Bureau of Land Management, Bureau of Reclamation, Bureau of Sport Fisheries and Wildlife, Bureau of Outdoor Recreation, Geological Survey.

Department of Agriculture - Soil Conservation Service

Department of Health, Education and Welfare

Department of Housing and Urban Development

Department of the Treasury

Department of Defense - Office of Naval Petroleum Reserves

Atomic Energy Commission

Federal Power Commission

Environmental Protection Agency

Non-Federal Agencies and Organizations

State Agencies

- State of Colorado, Director of Natural Resources - Special Committee on Economics of Environmental Protection, Governor's Oil Shale Advisory Committee

- State of Utah, Department of Natural Resources - Committee on Environmental Problems of Oil Shale

- State of Wyoming, Department of Economic Planning and Development - Wyoming Oil Shale Environmental Planning Committee

Local Agencies

- Oil Shale Regional Planning Commission - Garfield, Mesa, and Rio Blanco Counties, Colorado

Private Groups

- Private Industry participants in the exploratory core drilling and tract nomination program included the following companies: American Petrofine Company of Texas, Ashland Oil, Inc., Atlantic Richfield Co., Barodynamics, Inc., Occidental Petroleum Corp., Geokinetics, Inc., Gulf Minerals Resources Co., Marathon Oil Co., The Oil Shale Corporation, Phelps Dodge Corp., Shell Oil Co., Sohio Petroleum Co., The Superior Oil Co. Sun Oil Co., Western Oil Shale Corp.

Conservation Groups which have participated in oil shale field trips and public orientation meetings have included: Denver Audobon Society, Colorado open Space Council, Thorn Ecological Institute, Colorado State Rehabilitation Sub-Committee

C. Field Briefings

The summary below recounts various meetings, briefings and field inspection tours in which Departmental staff have participated to in form interested parties of the proposed oil shale program.

DEPARTMENT OF INTERIOR

MAJOR OIL SHALE FIELD TRIPS
AND
PUBLIC ORIENTATION MEETINGS
FROM
June 1971 to July 28, 1972

PURPOSE	DATE	PLACE	REMARKS
Regional Development & Land use Planning Comm. Meeting	6/30/71	Rifle, Colo.	Regional Dev. & Land Use Plan. Comm. meeting with Piceance Creek Basin Region County Commissioners, mayors, and planning commissioners, briefing and slide show presentation
Denver Audubon Oil Shale Proposed Prototype Oil Shale Briefing Prior to Field Trip	7/13/71	Denver, Colo.	Slide show presentation before Denver Audubon Society describing the proposed prototype oil shale program along with discussion from several of the oil shale task force members and industry
Denver Audubon Oil Shale Tour	7/17-18/71	Piceance Creek Basin	Field trip to Colorado oil shale area and present industry operations
Colorado State Rehabilitation Subcommittee Field Trip	8/2-3/71	Piceance Creek Basin	Field study group considering further work for environmental protection
Colorado Open Space Council Environmental Briefing	8/5/71	Denver, Colo.	Briefing on proposed oil shale program announced June 29, 1971 - Council is composed of representatives of various environmental groups in the area
Secretary of the Interior Oil Shale Tour	8/20/71	Parachute Creek & Anvil Points	Field trip and briefing for Secretary, 2 senators, 1 congressman, Lt. Governor, government officials, industry officials and press
Brief Colorado Bar Association on proposed Prototype Program	10/15/71	Colorado Springs, Colo.	Slide - tape show presented at annual meeting and discussed.
Oil Shale Regional Planning Commission Tour	10/23/71	Piceance Creek Basin	Tour of Colony mine and facilities and Shell core drilling site and general Colorado oil shale area

PURPOSE	DATE	PLACE	REMARKS
Utah Geological Society Speech	11/71 (Estimated)	Salt Lake City, Utah	Speech before Utah Geological Society presenting proposed oil shale program including slide show
Proposed Prototype Oil Shale Program Presentation	2/2/72	Boulder, COLO.	Oil shale talk including presentation of the prototype oil shale leasing program at the University of Colorado Journal Club Meeting
Interior Department Public Relations Field Trip	2/6-8/72	Piceance Creek Basin	Tour for Mr. Charles Wallace, Interior Dept. Public Relations to the Basin and adjacent western slope areas
Proposed Prototype Oil Shale Program Presentation	3/72	Denver, Colo.	Youth Advisory Board to the EPA - National meeting at the Cosmopolitan Hotel
Proposed Prototype Oil Shale Program Presentation	4/72	Vernal, Utah	Slide show and discussion of the proposed prototype oil shale program before the Kiwanis Club
Rocky Mountain Oil & Gas Assn., Synthetic Fuels Div., Speech	4/72	Billings, Mont.	Speech at mid-year meeting, presented the proposed prototype oil shale program with progress report on current oil shale activities
Proposed Prototype Oil Shale Program Presentation	5/72	Glenwood Springs, Colo.	Slide show and discussion of the proposed prototype oil shale program before the National Society of American Foresters
Field Trip for the Public	5/11-14/72	Wyoming Colorado Utah	Field tour for the public to inspect selected oil shale tracts W-a & W-b (Wyoming), C-a & C-b (Colorado) and U-a and U-b (Utah)
Secretary Oil Shale Briefing	6/28/72	Denver, Colo.	Briefing for Secretary of Interior, Rogers C. B. Morton- News Release same date
Thorne Ecological Institute Field Trip	6/30-7/5/72	Aspen, Colo. and surrounding areas. Incl. Piceance Creek Basin	Sixth National Seminar on Environmental Arts & Sciences

PURPOSE	DATE	PLACE	REMARKS
Field Trip for the Public	7/13-16/72	Wyoming Colorado Utah	Field tour for the public to inspect selected oil shale tracts W-a & W-b (Wyoming), C-a & C-b (Colorado) and U-a & U-b (Utah)

ACTIVITIES WITH WIDE-TIME FRAMES

Denver Audubon Meetings	6/71 to Present	Denver, Colo.	Several Denver meetings during the period from June 1971 to present
Oil Shale Regional Planning Commission Meetings	6/71 to Present	Rifle, Colo.	Field trips to western slope areas, mainly Rifle CO, to attend some 15 (estimated) meetings of the Oil Shale Regional Planning Comm.
Colorado Open Space Council Meetings	6/71 to Present	Denver, Colo.	Several COSC meetings during June 1971 to present
State of Colorado Oil Shale Planning and Coordination Committee	6/21/71 to Present	Denver, Colo.	Environmental oil shale problems committee (State of Colorado) cooperative studies-multiple meetings
Oil Shale SLUP Applications Inspections	September thru Nov. 1971	Piceance Creek Basin, Uintah Basin	Multiple field trips to inspect SLUP applications prior to approval by multidisciplined inspection group and Agencies
Oil Shale SLUP Drilling, Monitoring, and Inspection	10/15/71 thru Present	Piceance Creek Basin Uintah Basin	Multiple field trips to examine and inspect oil shale Core drilling permits, drilling activities and procedures

D. Coordination in Review of the Draft Statement

A formal Oil Shale Task Force has been established to provide a close liaison between those disciplines that have a major bearing on oil shale development.

This Task Force is headed by an Oil Shale Coordinator (Washington, D. C.), and a Deputy Oil Shale Coordinator (Denver, Colorado), jointly appointed by the Assistant Secretary--Mineral Resources and the Assistant Secretary--Public Land Management, to whom the Coordinators are responsible.

Department of Interior advisors to the Oil Shale Task Force include representatives from the Office of the Assistant Secretaries for Program Policy, Minerals Resources, Public Land Management, Fish and Wildlife and Parks, Water and Power Resoures, and the Solicitor's Offices. In addition, 10 Bureaus and Offices within this Department have assigned 28 professionals to participate as Task Force Members and/or advisors, including the Bureau of Sport Fisheries and Wildlife, Bureau of Land Management, Bureau of Mines, Bureau of Reclamation, Bureau of Indian Affairs, Bureau of Outdoor Recreation, National Park Service, Geological Survey, Office of Oil & Gas, and Office of Coal Research.

In addition to Interior, the following agencies have supplied materials, expertise, and reviews of the Draft Statement, through the participation of their representatives or advisors to the Task Force:

Department of Agriculture - Forest Service and Soil Conservation Service;

Department of Defense - Office of Naval Petroleum Reserves;

Department of Health, Education & Welfare;

Department of Housing and Urban Development;

Atomic Energy Commission;

Federal Power Commission;

Environmental Protection Agency.

For the present Draft Environmental Statement comments are being solicited from the following Federal, State, and private sources:

Federal Sources

Environmental Protection Agency
Department of Commerce
Department of Transportation
Atomic Energy Commission
Federal Power Commission
Office of Emergency Preparedness
Department of Defense
Office of Naval Petroleum and Oil Shale Reserves

State Sources

Colorado Department of Natural Resources
Utah Department of Natural Resources
Wyoming Department of Economic Planning & Development
Oil Shale Regional Planning Commission (of Garfield, Mesa and Rio Blanco Counties, Colo.)

Private Organization

Natural Resources Defense Council
Rocky Mountain Center on Environment
University of Wisconsin, Glen D. Weaver
Colorado Open Space Council
Sierra Club
Wilderness Society
National Audobon Society
National Recreation and Park Assoc.
Wildlife Management Inst.
National Wildlife Federation
Issac Walton League
Environmental Action
Friends of the Earth
Environmental Policy Center
Conservation Foundation
Nature Conservancy
American Forest Ass.
Center for Law and Social Policy
Environmental Defense Fund
Colorado Sportsmen's Association
Rocky Mountain Sportsmen's Federation
National Council of Public Land Users
Utah Wildlife Federation
Wyoming Open Space Council

Industrial Sources

American Petrofina of Texas
Ashland Oil, Inc.
Atlantic Richfield Co.
Barodynamics, Inc.
Occidental Petroleum Corp.
Geokinetics, Inc.
Gulf Minerals Resources Co.
Marathon Oil Co.
The Oil Shale Corporation
Phelps Dodge Corp.
Shell Oil Co.
Sohio Petroleum Co.
The Superior Oil Co.
Sun Oil Co.
Western Oil Shale Corp.

Industrial Sources (Continued)

Cameron Engineers
Mobil Oil Co.
Chevron
Equity
Cities Service Oil Co.
Carter
Union Oil Co.
Getty Oil Co.
Development Engineering

E. Proposed Schedule of Future Actions

The schedule of future activities shown below is proposed, following issuance of the draft impact statement:

1. Approximately 30 days after date of issuance of the statement, public hearings thereon would be held by the Department in the following locations: Denver and Grand Junction, Colorado; Salt Lake City and Vernal, Utah; Cheyenne and Rock Springs, Wyoming. Written comments would be received for a period of 45 days after the issuance of statement.

2. No earlier than 90 days after issuance of the Draft Impact Statement, in accordance with the National Environmental Policy Act or later if is required for revision, the Final Environmental Impact Statement for the Prototype Leasing Program would be issued, providing that a decision is reached to implement the proposed leasing program.

3. Approximately 30 days after issuance of the Final Environmental Impact Statement a Notice of the proposed lease sale would be published, fixing the date of the first sale 30 days after initial publication of Notice.

4. The six lease sales would be held in sequence, at 14 day intervals, in the appropriate State Bureau of Land Management offices. The proposed order of sale would be Tracts C-a, U-a, W-a, C-b, U-b, W-b.

Prior to the approval of the detailed mining plan which is required by the third anniversary of the lease for each of the selected tracts, the Deputy Field Oil Shale Coordinator would hold public hearings on these plans for each tract, in the county in which the tract is located. Members of the Oil Shale Field Task Force would participate, in order to receive comments from the interested public. It would be the purpose of these hearings to provide an opportunity for orientation and briefings on the environmental considerations involved in implementing the mining plan on each tract.

F. Comments Received

The preliminary draft statement released on June 29, 1971 invited comments but stated that it would not be complete until supplemented with specific tract information. As the statement has been revised and is being issued as a completed draft statement, it is open to comment in its entirety. Three pertinent reviews or critiques of the original statement have, however been submitted or made public, and are reproduced herein. They are: "memorandum of 7/19/71 to Environmentally concerned citizens" from Roger P. Hansen, Executive Director, Rocky Mountain Center on Environment; "Critical Review of the U. S. Department of the Interior Draft Environmental Impact Statement for the Prototype Oil Shale Leasing Program", dated October 18, 1971, by Glen D. Weaver of the University of Wisconsin, as submitted to the Senate Interior Committee for the November 15 hearing on Senate Bill S-2510; February 29, 1972 , and comments of the Natural Resource Defense Council on the preliminary draft impact statement, submitted to Assistant Secretary of Interior for Program Policy.

The Department of the Interior has obtained considerable more information from informational core drilling and related analysis, on-site inspections, and additional detailed studies. This new information and comprehensive analysis of energy alternatives have been compiled into a three-volume text which is approximately 10 times larger than the preliminary draft statement released on June 29, 1971. Because the scope of the effort has been greatly expanded, a detailed discussion of each review of the original statement is not presented below. Rather, each of the respondant will be provided a copy of the revised material and be invited to offer revised comments.

1. <u>Comments of Roger Hansen, Executive Director of Rocky Mountain Center on Environment</u>.

ROMCOE

ROCKY MOUNTAIN CENTER ON ENVIRONMENT
5850 East Jewell Avenue • Denver, Colorado 80222 • 303/757-5439

MEMORANDUM 7/19/71

TO: Environmentally Concerned Citizens

FROM: Roger P. Hansen, ROMCOE Executive Director

RE: Proposed Prototype Oil Shale Leasing Program

In response to considerable citizen concern over the environmental aspects of an oil shale leasing program felt by many to be imminent and without adequate environmental safeguards, this memorandum has been prepared as a public service. The memorandum is based entirely on representations made by the Department of the Interior in a "Program State for the Proposed Prototype Oil Shale Leasing Program" and dated June 1971. The memorandum is not intended as a critique of the Program Statement, which undoubtedly will be criticized by some environmental interests.

BACKGROUND

On June 4, 1971, as part of a special message to the Congress on "Clean Energy," President Nixon requested the Secretary of the Interior to proceed with the orderly development of an oil shale leasing program. The proposal put forward to the President and the Senate by the Secretary of the Interior outlined a plan "whereby the Department of the Interior, other Federal agencies, the States, the public and industry can all participate in creating a program which may permit the orderly development of our vast oil shale resources while at the same time assuring the minimum possible impact on the environment."

A "Program Statement for the Proposed Prototype Oil Shale Leasing Program" and a Draft Environmental Impact Statement were released by the Secretary on June 29, 1971. The prototype program would involved the selection of up to 6 oil shale tracts, 2 each in Colorado, Utah and Wyoming, to be offered for lease by sealed, competitive bid late in 1972. Each tract would include 5,120 acres, or a total of 30,720 acres. This compares to the approximately 17,000 square miles (11 million acres) of oil shale lands potentially valuable for commercial development.

The goal of the proposed Interior program will be "to provide a new source of energy for the Nation" by stimulating the development of oil shale by private enterprise "in a manner that will assure the minimum possible impact on the present environment."

The specific objectives of the oil shale leasing program are:

1. To provide a new source of energy to the Nation.

2. To insure the environmental integrity of the affected areas and develop a full range of environmental safeguards and restoration techniques that can be "reasonably" incorporated.

3. To permit an equitable return to all parties in the development of a "public" resource.

4. To develop management expertise in leasing and supervision of oil shale development.

An oil shale leasing program is also subject to the Mining and Minerals Policy Act of 1970 which has as one of its purposes: "the study and development of methods for the disposal, control and reclamation of mineral waste products and the reclamation of mined land, so as to lessen any adverse impact of mineral extraction and processing upon the physical environment. . . ."

The announcement of Interior's plans to proceed with the prototype program has resulted in immediate concern by citizen environmentalists. Their concern is principally threefold: (1) that the initial core drilling phase of the program will be undertaken without adequate environmental safeguards; (2) that environmental statements will not be filed on individual leasing sites; and (3) that the program itself will be implemented without sufficient opportunity for the public, and particularly environmental groups, to be heard on the various aspects of the program. The purpose of this memo is to provide additional information concerning these vital concerns.

DISCUSSION

1. Core Drilling.

At this time, specific sites have not been nominated for development. On June 30, 1971, official notice was published announcing that applications may be filed with the Bureau of Land Management for special land use permits to conduct informational core drilling in the oil shale region. A principal purpose of the core drilling is to provide the government with information needed to assess the probable environmental impact of oil shale development at particular potential lease sites. Applications must be approved by Interior, and Interior field officials will supervise drilling to insure compliance with regulations designed to avoid environmental damage. (43 Code of Federal Regulations, Part 23) Each permit will incorporate performance requirements necessary to accomplish this objective, and data obtained from drilling must be shared with Interior. Applications must also include a description of the proposed exploration program and the number and location of holes to be drilled.

The Bureau has emphasized that a careful environmental analysis will be made of each proposal for core drilling. Particular attention will be given to the extent and location of any new roads which would be required and their compatibility with existing uses and values, and spacing of any multiple drilling sites. An applicant for a permit must afford other parties a period of at least 120 days in which to participate in his proposed drilling program and to share expenses on a pro rata basis. This participation option should minimize the danger of multiple roads and multi-company operations in any one area which would produce unacceptable environmental damage.

Interior's draft environmental impact statement points out that to date, about 340 core holes have been drilled in the oil shale region, 225 in Colorado, and that no significant environmental impact has been observed.

2. Environmental Studies for Each Site

Environmental studies for the entire oil shale region were initiated in May, 1970 with a request by the Secretary of Interior to the Governors of Colorado, Utah and Wyoming. Following reports from the individual states (which were criticized in a number of respects by environmentalists), a seven-month study of typical lease sites was undertaken, involving 150 professionals with diverse backgrounds and resulting in a Draft Environmental Impact Statement as required by Section 102(2)(C) of the National Environmental Policy Act. According to the Program Statement, this draft statement included input from "independent conservation groups" which are not identified. Review emphasis was placed on: air quality standards; surface and ground water quality; land restoration; wildlife habitat; and scenic and esthetic values.

After informational core drilling has nominated the shale areas of greatest commercial potential, environmental impacts are to be assessed for those specific sites. Among the additional factors to be considered: existing and anticipated land uses; indigenous plant and animal life; aquatic resources; historical resources; archeological resources; and scenic attractions. The mining-wastes disposal system contemplated for the actual site will be evaluated. According to the Program Statement:

> Where there is a distinct probability that operations would have an unacceptable impact on existing resources, or where there are apparent unacceptable risks, nominated sites will be eliminated from subsequent considerations in accordance with the criteria for lease rejection which have been clearly enumerated.

The criteria for lease rejection are contained in Chapter IV of the Draft Environmental Impact Statement for a Prototype Oil Shale Leasing Program. There are 14 specific criteria, including: uncontrollable erosive waste or spent shale piles; leaching of deleterious substances which will degrade surface or ground water systems; creation of disturbed areas not susceptible to revegetation; emissions generated by processing plants which could contribute to environmental degradation; and loss of critical fish and wildlife habitat for which no alternative resolution is available.

Environmental information developed for each specific site which is a candidate for leasing will be published as a supplement to the Draft Environmental Impact Statement.

Following the actual leasing of specific sites, environmental investigations will continue to compare actual environmental impact with the projected impact. This will include air and water quality monitoring and studies on other resources such as agriculture, fish, wildlife, recreation and esthetics.

3. Public Participation.

Based upon the results of core drilling, certain areas will be nominated as potential lease sites. Nominations will be carefully reviewed by Interior, with the aid of the special oil shale advisory panels already designated by the governors of the three states involved.

In the spring of 1972, a supplement to the draft environmental impact statement will be circulated. It will deal in detail with the specific sites nominated for leasing. Public hearings will then be held, based upon the draft environmental impact statement and the supplemental site evaluations. A final environmental impact statement on the sites chosen for possible leasing will be submitted to the Council on Environmental Quality before a decision is made whether to proceed with lease sales. Thus, all available information pertaining to environmental impact will be made available for public review. Environmentally oriented groups will therefore have ample opportunity to participate in the development and review of the proposed program. The Secretary of Interior has stressed that no final decision will be made to proceed with the prototype leasing program before the mid-summer of 1972 after supplemental environmental information on specific possible lease sites has been published and public hearings held.

LEASES WOULD NOT BE OFFERED BEFORE DECEMBER, 1972.

Should prototype leases eventually issue, the Department will monitor operations and require changes, as needed, to mitigate adverse environmental effects. No federal leasing of oil shale lands beyond the proposed program, if implemented, will be carried out until the environmental effects of the prototype program indicating feasibility of developing a mature industry are fully evaluated. At that time another environmental impact statement would be published for public review.

PLANNING SEQUENCE

1. October 1969 -- Oil shale study initiated by Department of the Interior.
2. October-December 1969 -- Review of Mineral Leasing Act and previous oil shale leasing efforts.
3. December 1969 -- Establishment of Interior's Oil Shale Task Force.
4. May 1970 -- Proposed program presented to Secretary, who asked for additional environmental studies.
5. May-June 1970 -- Formation of Governor's committees in Colorado, Wyoming and Utah to study environmental impact and cost of environmental controls.
6. June 1970 -- Public meetings held in each state.
7. August 1970 -- Oil shale tour for private, State and Federal officials.
8. August to December 1970 -- Deputy Oil Shale Coordinator participated in 14 public oil shale meetings with environmental gorups and other public bodies. (ROMCOE not aware of this.)

9. <u>February 1971</u> -- Formal transmittal to the secretary of state government environmental impact analysis.

10. <u>March-June 1971</u> -- Preparation of Interior's Draft Environmental Impact Statement, pursuant to Section 102(2)(C) of the National Environmental Policy Act.

11. <u>June 1971</u> -- Draft Environmental Impact Statement submitted for public review.

12. <u>June 1971</u> -- Authorization of core drilling in Colorado, Utah and Wyoming.

13. <u>Fall 1971</u> -- Open Lease Nomination period.

14. <u>Fall 1971</u> -- Legal opinion from Interior Solicitor on "The propriety of leasing oil shale lands."

15. <u>Fall 1971</u> -- Publication in <u>Federal Register</u> of proposed lease terms and regulations for prototype program.

16. <u>Winter 1971-Spring 1972</u> -- Environmental impact studies for nominated sites.

17. <u>January 1972</u> -- Close period for receipt of lease nominations.

18. <u>Spring 1972</u> -- Publication of detailed environmental information on potential sites for leasing; hold public hearings on Draft Environmental Statement and supplement.

19. <u>Summer 1972</u> -- Publish Final Environmental Impact Statement.

20. <u>Fall 1972</u> -- Establish environmental standards to be incorporated into each oil shale lease; close evaluation core drilling.

21. <u>December 1972</u> -- Begin lease sales -- one tract every 2 weeks for total of 6 tracts.

22. <u>Early 1973</u> -- Issue lease(s) upon receipt of acceptable offer(s).

23. 1973 on -- Monitor all operations and require changes as needed to mitigate a adverse environmental effects.

BIBLIOGRAPHY AND AVAILABLE MATERIALS

Draft Environmental Impact Statement for the Prototype Oil Shale Leasing Program. U.S. Department of the Interior. June 1971. U.S. Geological Survey, Public Inquiries Office, 1012 Federal Building, Denver, Colorado 80202. $2.00.

Program Statement for the Proposed Prototype Oil Shale Leasing Program. U.S. Department of the Interior. June 1971. U.S. Geological Survey, etc. $2.00.

Report on Economics of Environmental Protection for a Federal Oil Shale Leasing Program. Special Committee of the Governor's Oil Shale Advisory Committee, State of Colorado. January 1971. U.S. Geological Survey, etc. $2.00.

Environmental and Economic Report on Wyoming Oil Shale. Wyoming Oil Shale Environmental Planning Committee. February 1971. U.S. Geological Survey, etc. $2.00.

Environmental Problems of Oil Shale. Committee on Environmental Problems of Oil Shale, State of Utah. February 19, 1971. U.S. Geological Survey, etc. $2.00.

A Critical Review of Environmental Protection for a Federal Oil Shale Leasing Program. Roger P. Hansen, Rocky Mountain Center on Environment, 4260 East Evans, Denver, Colorado 80222. March 1, 1971. No charge.

2. Comments by Glen D. Weaver Department of Geography, University of Wisconsin-Milwaukee. (See S2510 hearings, p.18-26.)

UNIVERSITY OF WISCONSIN,
DEPARTMENT OF GEOGRAPHY,
Milwaukee, Wis., October 18, 1971.

Senator Frank E. Moss,
Subcommittee on Minerals, Materials, and Fuels, Committee on Interior and Insular Affairs, Washington, D.C.

DEAR SENATOR MOSS: Please include the attached document in your upcoming hearings on the Department of the Interior prototype oil shale leasing program.

I do not oppose leasing of federal shale lands per se. However, the attached Review paper and Environmental Hazards study indicate that Interior's draft environmental impact statement provides insufficient information and analysis for effective public decisionmaking.

I sincerely hope that your Subcommittee hearings will elicit testimony from a wide spectrum of interests. My involvement in oil-shale research over the past three years leads me to believe that the basic data needed for decisionmaking can be assembled in the type of public forum your Subcommittee hearings will provide.

Respectfully,

Glen D. Weaver,
Instructor in Geography.

Enclosure

CRITICAL REVIEW OF THE U.S. DEPARTMENT OF THE INTERIOR DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE PROTOTYPE OIL SHALE LEASING PROGRAM

Glen D. Weaver
Department of Geography
University of Wisconsin-Milwaukee

October 18, 1971

Scope of Study

Interior's Impact Statement[1] considers only those lands directly involved in the prototype leasing program, or about 0.5 percent of the total oil-shale area having present or potential economic interest. The study does not project the effects of a mature oil-shale industry, it does not consider the cumulative effects of oil-shale development over time, nor does it adequately appraise the potential impact of oil-shale development on water resources in the Lower Colorado River Basin.

The environmental impact of a prototype program, affecting only a small area for a limited time period, is obviously far different from the impact of a large-scale industry operating for many years. This failure to consider large-scale and long-range consequences is analogous to Interior's handling of the Santa Barbara disaster, whereby the effective decision to permit oil production was made as a routine matter when the oil companies were permitted to explore for oil in the Channel. After the oil was discovered, and after millions of dollars had been spent in finding it, the Interior Department was understandably reluctant in denying the companies' demands for production rights. I foresee the same situation occurring with respect to oil shale; i.e., if the prototype program demonstrates the private profitability of oil shale, Interior will be in a difficult position to shut down the industry even if the environmental effects prove to be grossly unacceptable.

Inasmuch as the oil-shale region forms a major portion of the Upper Colorado River Basin, it seems equally incredible that Interior should neglect a detailed examination of potential impacts on downstream water quality. This is an especially critical ommission since the waters of the Colorado River are subject to both interstate and international compacts.[2]

Land Reclamation

Interior's comments on land reclamation deserve very careful reading. Consider the following:

> Page III-9: "In the long-term, open pits refilled with over-burden and processed spent shale could be revegetated and re-stored to a reasonable approximation of their original state."
>
> Page III-19: "To prevent future ground water contamination (from leaching of spent shale), however, it may be necessary to construct a permanent impermeable floor where the waste material is to be deposited."
>
> Page III-11: "It has been experimentally demonstrated that vegetation can be grown on processed oil shale with adequate reseeding, fertilization, and watering. For example, Kentucky blue grass, western wheat and crested wheat have been success-fully grown, and initial findings indicate that, once established, <u>some</u> of these species <u>may</u> become permanently established with-out further maintenance. . . However, a significant body of re-search experience indicates that re-establishment of the fuller range of native browse and cover species, such as mountain mahogany, shadbush and bitterbrush, is <u>difficult and time-consuming</u>." (Underlining added)

In other words, backfilling of open pits (or underground mine sites) with processed spent shale may contaminate ground waters and surface waters receiving ground-water base flow unless the pit floors and sides are per-manently sealed. Also, revegetation of the backfolled surface to pro-vide a good wildlife habitat will be "difficult and time-consuming," if not altogether infeasible.

I find it unreasonable to assume that open pit mines would be com-pletely backfilled under any circumstances. Both overburden and spent shale would have to be stored off-site during initial years of pit development, which Interior estimates to be six years for a 50,000 bbl/day open-pit operation (p. III-7--III-8). Returning this stored material to the mine site would involve tremendous economic expense.

Furthermore, since the shale volume after retorting <u>exceeds</u> the in-place volume before mining, it is patently impossible to return all of the spent shale waste and overburden to the mine site without creating an elevated land surface.

Should oil-shale development evolve into a million barrel per day industry, it would generate enough spent shale in a year's time to cover an area the size of Washington, D.C., to a depth of six feet.[3] Wherever stored, the spent shale must be <u>permanently</u> shielded from percolating groundwaters and surface runoff. Engineering safeguards may be effective during the lifetime of the oil-shale plant, but who is to maintain the protection works after the site is abandoned? Will diversion structures and retention dams in canyon sites be built to withstand the 10-year, 100-uear, or 1,000-year flood? Unfortunately these questions are not even raised, much less answered, by the Interior study.

Water Quality

According to the <u>Impact Statement</u> (p. III-16--III-17), all foreseeable water quality problems are "controllable with present technology" and the goal of the ptototype leasing program is to permit "no degradation in the quality of the naturally occurring waters of the oil shale region."

The goal of "no degradation" is patently impossible in an operational sense, as the prototype program will divert and consumptively use water from the Colorado River or its tributaries. Consumptive use inevitably reduces the quantity of water available for dilution of downstream pollution loadings. Unfortunately, oil-shale processing will be a high-consumptive use industry (e.g., page V-3 of the Impact Statement indicates that 40 to 63 percent of the water diverted will be used consuptively). One must also question whether the quality of return flows from oil-shale processing and related urban requirements can be kept within the "no degradation" goal.

Here I would again point out the need for assessing the impact of a mature industry rather than simply considering the impact of a prototype program.

Additionally, it is completely unrealistic to divorce the impact of oil-shale from other water-using developments expected to accrue in the Colorado River Basin. For example, the Colorado River Basin Water Quality Control Project[4] estimates that the salt load of the Colorado River at Hoover Dam will increase from its present 725 ppm to 947 ppm by the year 2010. Most of the increased salt load is projected on the basis of increased consumptive use of water in the Upper Basin without an oil-shale industry. Conclusion: If the oil-shale industry achieves its "no degradation" goal, it will indeed be unique.

Air Quality

The Impact Statement (p. III-22--III-24) fails to consider the air pollution meteorology of the oil-shale region. This is particularly serious, inasmuch as valley locations throughout the region are characterized by persistent nocturnal temperature inversions which favor accumulation rather than dispersion of atmospheric contanimants.[5,6] Unfortunately, valley locations are also favored spots for the siting of aboveground crushers and retorts, refinery plants, electric-power generating facilities, and new population centers.

Unless stringent emmission standards are adopted, the oil-shale region could become another Four Corners disaster area in terms of air quality.

Wildlife Resources

Interior (p. V-6) acknowledges that certain wildlife populations, such as mountain lion, bear, elk, and mule deer, would decline as a result of the prototype program. The declines are not expected to be "dramatic," but this assumption is predicated upon the effects of a prototype program only. Entirely neglected are the potential effects of a mature industry operating over many years and possibly disturbing several thousand square miles of land.

All oil-shale areas of major economic interest presently contain large and varied wildlife populations. Colorado's Piceance Creek Basin, for example, provides summer range or critical wintering grounds for up to 15 to 20 percent of the state's total mule deer population.[7] Since the late 1950's, however, forage and browse shortages have necessitated special post- and pre-season hunts in order to bring the herd size into equilibrium with the available resources.[8] Any increased industrial activity in the basin would simply mean more adversity for wildlife, in general, and deer, in particular.[9]

In-Situ Processing

The Impact Statement (p. III-38--III-39) gives an extraordinarily brief and superficial evaluation of the environmental effects of in-situ processing' yet proposes to allow "limited in-situ operations' in the current leasing program.

As discussed in a companion study,[10] in-situ recovery of shale oil poses numerous environmental threats. These hazards should be carefully examined in conjunction with on-going field projects being conducted by the U.S. Bureau of Mines, Equity Oil Company, and Shell Oil Company before any consideration is given to promoting additional experiments.

Alternative Energy Sources

Interior's prototype oil-shale leasing program should be assessed against alternative methods of meeting the Nation's long-term energy needs. The alternative adjustments include:

1) increasing the rate of domestic crude oil exploration;
2) increasing the rate of domestic crude oil recovery;
3) increasing the quantity of allowable foreign imports of crude oil and oil products;
4) developing synthetic liquid fuels from coal and tar sands;
5) substituting with such non-liquid energy sources as nuclear fuels, hydropower, and solar power; and
6) increasing the efficiency of energy utilization and/or decreasing the demands for energy.

Interior has dealt with some of these alternatives in a related report.[11] The discussion of alternative 4 (liquifaction of coal) is particularly weak, however, Alternative 6 has been neglected entirely despite its tremendous relevance to the issue of whether oil-shale development is in the best overall public interest.

References

1 U.S. Department of the Interior, 1971, Draft environmental impact statement for the prototype oil shale leasing program: Washington, D.C., U.S. Dept. Interior.

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5 Holzworth, G. C., 1962, A study of air pollution potential for the western United States: Jour. Applied Meteor, v. 1, p. 366-382.

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9 Baker, B. D., 1970, Big game winter range analysis, Game Unit 22--Piceance: Fort Collings, Colo., Wildlife Research Center, p. 10.

10 Weaver, G. D., 1971, Program statement for the pro-
in-situ methods: Milwaukee, Univ. Wis.--Milwaukee, Dept. Geography mimeo, 67 p.

11 U.S. Department of the Interior, 1971, Program statement for the proposed prototype oil shale leasing program: Washington, D.C., U.S. Dept. Interior, p. VI-1--VI-26.

3. Comments by Natural Resources Defense Council, Inc.

Natural Resources Defense Council, Inc.

1600 TWENTIETH STREET, N.W.
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New York Office
36 WEST 44TH STREET
NEW YORK, N.Y. 10036
212 986-8310

February 29, 1972

Mr. John W. Larson
Assistant Secretary for Program Policy
Department of the Interior
Washington, D. C. 20240

Dear Mr. Larson:

Enclosed are the comments of the Natural Resources Defense Council on the Draft Environmental Impact Statement for the Prototype Oil Shale Leasing Program issued by the Department in June, 1971. We find the draft statement inadequate both in scope and content to comply with the requirements of the National Environmental Policy Act, 42 U.S.C. §§ 4321 et seq., primarily due to the omission of (1) material environmental impact information and (2) detailed discussion of reasonable alternatives to the prototype oil shale leasing program and their environmental impacts. We believe, therefore, that the Department should prepare and circulate a new draft statement.

Sincerely yours,

Thomas B. Stoel, Jr.

Edward L. Strohbehn, Jr.

encl.

cc: Mr. Burton W. Silcock
Director
Bureau of Land Management

Natural Resources Defense Council, Inc.

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Comments of

Natural Resources Defense Council

on

Prototype Oil Shale Leasing Program

Draft Environmental Impact Statement

Submitted by:

Thomas B. Stoel, Jr.
Edward L. Strohbehn, Jr.
February 29, 1972

I. INTRODUCTION

The Natural Resources Defense Council (NRDC) finds this draft statement inadequate, both in scope and content, to comply with the requirements of the National Environmental Policy Act (NEPA), in particular sections 102(2)(C) and (D).[1] NRDC's comments will focus on the major deficiencies, which consist primarily of omissions of (1) material environmental impact information and (2) detailed discussion of reasonable alternatives to the prototype oil shale leasing program and their environmental impacts. Although this draft statement is only a preliminary statement, the Department has indicated that the supplemental statement will be concerned only with the environmental impacts of the proposed program on the specific tracts to be leased.[2] Therefore, NRDC believes that the Department

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1 / 42 U.S.C. §§ 4332(2)(C),(D).

2 / U.S. Dept. of the Interior, Prototype Oil Shale Leasing Program Draft Environmental Impact Statement i, II-4 to -5 (June 1971) [hereinafter cited as Draft Statement].

should prepare and circulate a new draft environmental impact statement which discusses in detail the environmental impact of the oil shale leasing program and its reasonable alternatives.[3]

II. ENVIRONMENTAL IMPACT

A. Of Prototype Leasing Program.

The discussion of environmental impact of the proposed program is seriously inadequate in a number of areas.

1. Land. The draft statement details the mammoth amounts of waste shale that will be generated by the prototype leasing project and indicates that the wastes will be disposed of by filling canyons and the open pits caused by strip mining. These disposal sites will then be restored through revegetation. The draft statement does not state whether and to what extent growing vegetation on the waste piles of processed shale depends on continued fertilization and watering. The statement notes that "additional investigation" is needed to determine if processed shale can

3 / Natural Resources Defense Council, Inc. v. Morton, Dkt. No. 2397-71 (D.D.C. filed Feb. 1, 1972).

support long-term vegetation.[4] Since only *in situ* processing does not produce large piles of processed shale waste and this is the least likely process to be used,[5] whether long-term vegetation can be supported on shale wastes is critical to determining whether the Department can meet its irrevocable commitment to maintain the integrity of the environment.[6] These wastes will amount to about 1500 acres per lease over the twenty-year period of production presently contemplated.[7] Before the Department undertakes the prototype program, the Department must discover by investigation and present in its draft statement reliable information regarding the viability of revegetation.

2. Water supply and quality. The draft statement states that at the end of six years the prototype leasing program will require approximately 30,000 acre-feet of water annually from the Upper Colorado

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4 / *Draft Statement* III-11.

5 / *Id.* at III-38 to -39.

6 / U.S. Dept. of the Interior, Press Release of June 29, 1971, "Secretary Morton Announces Draft of Interior's Plans for 'Prototype Program' of Oil Shale Development" at 2.

7 / *Draft Statement* III-6.

River Basin, of which 11,000 to 18,000 acre-feet would be treated for further use and discharged. The draft statement does not discuss what processes will be used to meet the "no degradation" goal adopted by the Department[8] and how reliable these processes are. The draft statement also fails to provide detailed information concerning the total water resources available and the water requirements of the prototype program and its important constituent elements, such as the industry, the employees' families, and satellite services.[9] Since the region is semi-arid and since claimants for water from the Colorado River are many and primarily downstream, this

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8 / Id. at III-17.

9 / The 30,000 acre-feet water requirement noted in the draft statement apparently includes the needs of both the industry and the employees' families and satellite services. See U.S. Dept. of the Interior, Prospects for Oil Shale Development, Colorado, Utah, and Wyoming 99-100 (May 1968) [hereinafter cited as Prospects for Oil Shale Development (1968)]. Because of the critical importance of water to the maintenance of the area's environmental integrity, the operation of the oil shale industry, and the increased urbanization of the area, the water needs of each sector should be detailed in the statement. This is necessary because important decisions relate directly to the water resource requirements of these sectors such as their different water quality needs and effluent treatment requirements. Moreover, these three sectors are not the only ones for which water requirements are critical and for which the draft statement must provide detailed information. See note 18 supra.

information is of critical importance to the environmental and economic feasibility of the project. The draft statement must, for example, project the total water supplies available;[10] the frequency of drought years; the total demands for the water, including those of downstream claimants; and the demands of the major elements of the entire prototype program.

3. Recreation. One of the most important goals to which the Department has committed itself -- preserving the area's environment -- can only be achieved by assuring that present parks and wilderness areas are preserved and that other lands suitable for preservation as park and wilderness areas are set aside before the project begins. The draft statement suggests that presently designated parklands will be preserved but little additional land. The Department must discuss in detail its plans for preserving park and wilderness areas other than those presently designated, or state

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10/ If the total supplies include the treated effluent from the oil shale industry, the reliability of the treatment process and the probability of achieving a "no degradation" goal must be discussed in the draft statement.

why it has adopted a different policy. The Department should consider developing a nomination system, similar to the one it employs for selecting the oil shale lease tracts, and in which the public could participate, for determining which lands should be preserved for further development.

B. Of Full-Scale Oil Shale Industry.

The Department's oil shale leasing program is part of the "President's comprehensive energy program to help assure future energy supplies,"[11] which the President announced in his Energy Message of June 4, 1971. A primary goal of the prototype program is "to stimulate the development of commercial oil shale technology to ensure that oil from shale will be available as a future domestic supply option when needed."[12] The

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11/ U.S. Dept. of the Interior, Program Statement for the Proposed Prototype Oil Shale Leasing Program i (June 1971) [hereinafter cited as Program Statement].

12/ Draft Statement II-1. In the Department's publication United States Energy: A Summary Review (Jan. 1972) the objective of the program is stated to be: "To stimulate commercial development on public lands . . ." at 54. See also the Department's press releases of June 29, 1971, at 2, 4, and July 15, 1971, which transmits Secretary Morton's remarks to the National Petroleum Council, at page 6 of the remarks.

broad scope and objectives of the program are outlined in the Program Statement: "Through proper planning, it is believed that this proposed program would, on balance, benefit the nation as a whole as well as the oil shale region itself."[13] Discussion of the environmental impact of this broad program is entirely missing from the draft statement although it will be substantial: the region to be developed is a sparsely settled, semi-arid region with approximately three people per square mile; the nearest cities are more than 200 miles away.[14]

Since the Department has stated that it "is irrevocably committed to maintain[ing] . . . the environmental integrity of the oil shale area,"[15] detailed discussion, to the fullest extent possible, of the environmental impacts of a full-scale industry is necessary (1) to determine whether the prototype leasing method chosen involves adverse environmental impacts which would be apparent only after development of the larger industry and which could be avoided, and

13/ Program Statement ii.

14/ Draft Statement III-1.

15/ Note 6 supra.

(2) to an adequate evaluation of alternatives to the proposed prototype program. Examples of the kind of environmental impact information that must be presented and its relevance to these two issues follow.

1. Environmental impacts. The statement notes that certain wildlife species are insensitive to human encroachment. In general, the impact statement appears to assume that the impacts on such resources as air quality, fish and wildlife, and the land will be roughly proportional to population growth.[16] Detailed information to support such a conclusion must be included in the draft statement since it seems likely that the impacts of a full-scale industry as compared with the prototype would be more than proportional, making it extremely difficult to maintain the environment of the area. As one extremely important example, the statement notes that water is scarce in the oil shale area. The draft statement must present detailed information regarding the availability of water resources for meeting the enormous demands of a full-scale industry and the new inhabitants and supporting services such an industry will attract.

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2. Avoiding impacts caused by a full-scale industry. Unless attention is given to problems such as those just mentioned, options for avoiding or minimizing them may be foreclosed by decisions to accommodate the protype program. For example, the draft statement indicates that specific measures will be taken to minimize the adverse impacts on such resources as wildlife by providing lease conditions which "will assur[e] that the lessee would . . . protect fish and wildlife and their habitat from damage by mining and surface operations."[17] Under conditions of full-scale industry operation, it may be necessary to require not only more restrictive lease provisions than would be required for the prototype industry, but additional ones as well, both of which must also be applied to lessees under the prototype

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17/ Id. at IV-8.

program.[18] In particular, none of the contemplated lease provisions deal with the problems posed by increased urbanization of the area.

Two other examples deal with the problems posed by urbanization. If analysis indicates that there will be insufficient water resources to meet the needs of the industry and of employees' families

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18/ Similar issues arise with respect to the mineral extraction industry that may be developed. It is planned to permit the lessee to extract sodium mineral compounds or other minerals which occur in the leased lands intermixed and intermingled with deposits of oil shale. "Proposed Oil Shale Lease," Program Statement app. B, at B-1. No environmental impact information about such an industry is presented in the draft statement. Such information must be included in the statement since important decisions depend on it. For example, the statement must provide information regarding the availability of water resources for a mineral extraction industry as well as a full-scale oil shale industry. The Department's 1968 oil shale report stated that "the mineral-extraction industry would have to compete for water with oil-shale processing. When the size of the shale-oil industry approaches 1 million barrels per day in Colorado, the size of the mineral extraction industry may be limited by the availability of water since the water consumption for recovering minerals from a given sized shale-oil plant are several times higher than the maximum expected for all other processing operations (including oil shale) and for urban requirements." Prospects for Oil Shale Development (1968), at 73. Thus, the lease provisions may have to be changed to prohibit multiple mineral extraction operations. And if lessees cannot operate mineral extraction processes together with oil shale operations, the type of oil shale process chosen may differ as well as its environmental impacts.

located near the working sites, then decisions must be made now to ensure that no urban growth is permitted to occur within the area, a decision contrary to that proposed in the draft statement. If studies demonstrate that increased urbanization will have a relatively greater impact on fish and wildlife than expected, then more land must be preserved now to provide sanctuary and a buffer than would be required for the prototype program.

3. Evaluating alternative prototype programs. One example of the considerations involved in relating the environmental impact of the larger industrial program to decisions with respect to the prototype program concerns the problem of disposing of the mammoth amounts of waste shale which will be produced. Thus, at the prototype stage consideration ought to be given to encouraging the development of that process which minimizes this problem, rather than providing equal resources to alternative processes, and to locating the industry in a place where disposal problems are minimized, rather than choosing the area which has the richest shale.

III. ALTERNATIVES AND THEIR ENVIRONMENTAL IMPACTS

The draft statement considers only three alternatives to the proposed prototype leasing program, none of which involves resources other than oil shale or purposes other than development of an oil shale industry. Moreover, the entire discussion of alternatives to the proposed prototype program is encompassed in three double-spaced typed pages. This is not the detailed discussion of reasonable alternatives and their environmental impacts required by NEPA.[19]

Some of the reasonable alternatives, together with their environmental impacts, which are not discussed in the draft statement in the detail required by NEPA are described below. This list of examples is not inclusive; it is the duty of the Department, not of NRDC, to identify and discuss in detail all reasonable alternatives to this

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19/ 42 U.S.C. §§ 4332(2)(C)(iii),(D); Exec. Order No. 11514, § 2(b), 35 Fed. Reg. 4247 (1970); CEQ, Guidelines, § 6(a)(iv), 36 Fed. Reg. 7724 (1971); Dept. of Interior, "Statement of Environmental Impact," Dept. Manual, pt. 516, ch. 2, § .6.C(8), 36 Fed. Reg. 19343 (1971); Natural Resources Defense Council, Inc. v. Morton, Dkt. No. 71-2031 (D.C. Cir. filed Jan. 13, 1972), aff'g 3 ERC 1743 (D.D.C. 1971).

federal action.[20]

Two aspects of the prototype leasing program must be considered in determining the reasonable alternatives: (1) a substantial amount of federal research and development funds will be expended for studying and monitoring the program (this amount must be quantified in the statement); (2) a small operating oil shale industry will be developed which will produce about 200,000 barrels per day (b/d) of oil and will cause substantial adverse environmental impacts. Reasonable alternatives to the prototype program are:

A. Cancel or Delay Leasing.

1. Use the research and development (R&D) funds for R&D directed toward other energy sources such as:

(a) underground and/or aboveground storage of oil to make possible more oil imports;

(b) coal gasification and/or liquefaction;

(c) solar energy;

(d) magnetohydrodynamic power cycles (MHD);

20/ The Department itself has recognized their relevance by discussing several "available energy options" and "future supply options" to the oil shale leasing program in the Program Statement ch. VI, §§ B,D.

(e) nuclear stimulation of natural gas resevoirs;

(f) liquid metal fast breeder reactor (LMFBR);

(g) advanced reactor concepts other than the LMFBR, such as gas cooled, molten salt and light water breeder reactors;

(h) controlled thermonuclear fusion;

(i) improved techniques for finding and producing oil and gas, onshore and offshore;

(j) fuel cells;

(k) tar sands;

(l) developing methods of reducing the rate of growth of energy consumption.

The first alternative above -- developing underground and/or aboveground oil storage methods -- would permit essentially unlimited imports of oil while assuring national security, thus increasing the nation's oil supplies while probably causing relatively insubstantial adverse environmental impacts. An investment in this area could be extremely productive. The Cabinet Task Force on Oil Import Controls recommended study of this alternative in its report to the President in

February 1970.[21]

The next seven alternatives noted above were mentioned by the President in his Energy Message of June 4, 1971. In discussing these R&D programs, the President stated that the "key to meeting our twin goals of supplying adequate energy and protecting the environment in the decades ahead will be a balanced and imaginative research and development program."[22] The President's energy advisors have testified that the message was not such a program and that it remains to be developed.[23]

The Department discussed the next three alternatives -- among a number of others -- in its Program Statement on the oil shale program

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21/ Cabinet Task Force on Oil Import Control, The Oil Import Question ¶ 245; see also ¶ 419,424, app. J, ¶¶ 1-5 (Feb. 1970).

22/ President, White House Press Release, June 4, 1971, at 6.

23/ Paul W. McCracken, Chrm., Subcomm. on Nat'l. Energy Situation of Domestic Affairs Council (speaking for all subcommittee members), and Chrm., Council of Economic Advisors, at Hearings before the Comm. on Interior and Insular Affairs on The President's Energy Message, 92d Cong., 1st Sess. 7 (June 15, 1971).

and/or its recent publication -- United States Energy: A Summary Review.

The alternative of reducing the rate of growth of energy consumption is an available means for meeting energy needs. This alternative has not been studied by the government although its importance and relevance has been recognized. The Chairman of the Federal Power Commission, John N. Nassikas, delivered a statement to the Joint Committee on Atomic Energy in March 1971, which stated:

> Some have suggested that energy consumption is growing at too rapid a rate and thereby causing an excessive drain on our resource base, and that energy production is associated with large social costs which threaten to outweigh its benefits. This is a viewpoint which certainly deserves careful and thoughtful study . . . [24]

The Energy Policy Staff of the Office of Science and Technology stated in a report issued in 1970

24/ Statement of John N. Nassikas, Chrm., Federal Power Commission, Mar. 23, 1971, for the Joint Committee on Atomic Energy, U.S. Cong., at p. 1.

that the question of reducing the rate of growth in national power generation capacity "require[s] a great deal of public thought and discussion, for [the answers] will affect both the economy and the environment for decades to come."25

2. Obtain the 200,000 b/d of oil expected to be produced by the prototype oil shale industry instead from:

(a) increased oil imports;

(b) elimination of state market-demand prorationing;

(c) changing Federal Power Commission gas pricing policies; or

(d) reducing the rate of growth of energy consumption.

The oil import quota restrictions would have to be modified only marginally to meet the 200,000 b/d that would be produced by the prototype program, probably causing substantially less adverse environmental impacts. The Cabinet Task Force on Oil Import Controls recommended in 1970, by a five to two cabinet-level vote, that restrictions on oil

25/ Energy Policy Staff, Office of Science and Technology, Electric Power and the Environment 48 (Aug. 1970).

imports be considerably relaxed. The Task Force found that this would permit importation of several millions of barrels of oil per day without endangering national security.[26]

Recovery from existing oil fields in Louisiana and Texas could be increased on the order of 1.2 million b/d by eliminating the state market-demand prorationing system which restricts production in these states.[27] This could be accomplished by a Presidential proclamation suspending operation of the Connolly Hot Oil Act[28] and ensuing court action by the Federal Government under the Commerce Clause and antitrust laws; this same result could be obtained by congressional action repealing the Act. A study prepared for the Joint Economic Committee of the United States Congress suggested that the President is required to suspend the Act's operation

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26/ Cabinet Task Force on Oil Import Control, The Oil Import Question (Feb. 1970).

27/ Id. at ¶ 408.

28/ 15 U.S.C. §§ 715 et seq.

now because of the existing lack of supply-demand parity which unduly burdens interstate commerce.[29] The Cabinet Task Force on Oil Import Controls also discussed this alternative in its report, noting that the prorationing system would become pointless if import controls were significantly relaxed.[30]

Changes in the pricing policies of the Federal Power Commission would encourage exploration, discovery, and production of gas and oil. The Council of Economic Advisors has informed the President that "[t]he only satisfactory solution to this problem (of inadequate supply development) is to allow the price, at least of new gas not previously committed, to approach market clearing level."[31]

29/ U.S. Cong., Joint Economic Committee, Report on Crude Oil and Gasoline Price Increases of November 1970: A Background Study 92d Cong., 1st Sess. 15-19 (Nov. 3, 1971).

30/ Cabinet Task Force on Oil Import Control, The Oil Import Question ¶ 408 (Feb. 1970).

31/ Dept. of the Interior, United States Energy: A Summary Review 38 (Jan. 1972).

B. Modify the Prototype Leasing Plan.

1. Lease fewer tracts. The draft statement is based on leasing six tracts of land, two each in the states of Colorado, Utah, and Wyoming. The statement provides no information, however, about this decision. The prototype leasing program:

> seeks to establish a new cooperative effort between the private and public sectors to assess the complex relationship between the development of oil shale and environmental maintenance. By necessity existing technology would be modified and new technology developed both for extracting the oil and for reducing the environmental impact.[32]

The draft statement demonstrates that substantial adverse environmental impacts will occur even if only one tract is leased. It is not obvious that the experimental objectives of the program can best be met by leasing six tracts. The Department's 1968 oil shale report, for example, recommended that two tracts be leased.[33] The draft

32/ Draft Statement I-1.

33/ Prospects for Oil Shale Development (1968), at 129.

statement must discuss in detail the basis on which the decision to lease six rather than one, three, or ten tracts, for example, was made, and the environmental impacts of these reasonable alternatives.

2. Change lease conditions. The draft statement indicates that the principal measures adopted by the Department "to minimize and mitigate certain types of undesirable [environmental] impacts" are lease provisions[34] which "are designed to assure that the lessee would . . . [for example] protect fish and wildlife and their habitat from damage by mining and surface operations."[35] The specific lease provisions have not been formulated, however, and none of them deal with the

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34/ The Department has indicated that it will institute a monitoring program to aid in ensuring compliance with these objectives. The details of the monitoring program, such as personnel, equipment, and methods, are not mentioned in the draft statement. The monitoring program itself may be changed in the light of changed lease conditions and/or new law or regulations. Detailed discussion of the monitoring program must be presented in the impact statement, including whether such a program would be more effective if based on regulations rather than lease conditions.

35/ Draft Statement IV-8.

destructive impacts of increased urbanization. The draft statement must provide the actual language of the lease conditions. The statement must also identify, as appropriate, alternatives to these conditions and their relative expected effectiveness in avoiding or minimizing environmental impacts.

The draft statement suggests that the principal means of assuring adequate land reclamation and restoration is the bond requirement which lessees must post. The bond provisions have been drafted and provide that the bond amount may not be less than $500 per acre of land estimated to be affected nor less than $2000 in total.[36] This amount seems far too low[37] to ensure that "the approved development-restoration plan would be

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36/ Program Statement B-15 to -16.

37/ The January 1972 newsletter of the Conservation Foundation reports:

> One Bureau of Mines Study, completed in 1965, concluded that the cost of restoring a natural slope was $15.73 per linear foot of highwall, or about $2,700 per acre. In an Elkins, West Virginia, demonstration project, the average cost for reclamation of 561 acres, exclusive of clearing and vegetation, was $1,685 per acre. CF Letter, Jan., 1972, at 2.

See E.A. Nephew,"Healing Wounds", in 14 Environment no. 1, at 12, and report of J. McCaull, in id. at 14 (Jan./Feb. 1972).

conducted in a manner designed to avoid degradation of the environment and that all other related lease terms would be met."[38] The draft statement must provide detailed information with respect to the expected costs of land reclamation and restoration, the cost experiences of others, such as the Tennessee Valley Authority, and similar information on the related lease terms so that independent assessment of the proper bond amount may be made.

3. Enact environmental protection legislation and/or regulations in addition to or rather than relying on lease provisions. Federal law governing the development of an oil shale industry is probably ineffective for meeting the stringent environmental protection goals enunciated by the Secretary and the draft statement with respect to oil shale development.[39] This may explain why the lease

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38/ Draft Statement IV-9.

39/ Concerning federal control of strip mining, the CF Letter reports:

> The only existing federal control consists of Interior Department regulations for mining on public and Indian lands over which the federal government has jurisdiction. The record to date, however, suggests to many observers a need for substantial regulatory change. A maze of statutes, regulations, field manuals, bureaucracies and traditions governs the (cont.)

conditions are the principal method adopted by the Department for ensuring the environmental integrity of the area. Contract provisions may be much less effective than statutory or regulatory controls, however, The draft statement must analyze the relevant laws and regulations and discuss why the Department decided to rely

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39/ (cont.)
administration of coal strip mining on federal lands. Control functions are further hobbled by vague lines of authority, conflicting powers, and serious understaffing in critical positions.

The laws themselves do not even mention strip mining. Nor do they prohibit stripping in wilderness or proposed wilderness areas. . . .

. . .

At the heart of the administrative system are regulations promulgated in 1969 by Interior (43 CFR 23 and 25 CFR 177). They place great responsibility for environmental protection on the Bureau of Land Management and the U.S. Geological Survey, agencies which also are interested in facilitating the extraction of minerals. Like the state laws, these regulations do not apply retroactively . . . And even where they do apply, the regulations are weak. They grant the BLM and USGS no clear authority to prohibit stripping in particular regions. The regulations also do not authorize sanctions that could be applied quickly against a stripper who violates his mining or exploration plans. They do not provide specific reclamation standards. Staffing and inspection capabilities are sadly inadequate. In addition, the regulations provide little check on agency activities, for there are no provisions for public participation. CF Letter, January, 1972, at pages 11-12.

on contract law rather than seek appropriate legislation and/or develop regulations.

IV. CONCLUSION

NRDC believes that the draft statement is so inadequate in its discussion of both environmental impact and alternatives that the Department is required to issue a new draft impact statement which rectifies these inadequacies and on which interested parties may have an opportunity to comment. And NRDC believes that prior to issuing this new draft statement the Department is legally obliged to consult with (1) government agencies -- federal, state, and local -- other than the Department which have jurisdiction by law over any of the reasonable alternatives to the prototype oil shale program; and (2) federal agencies having jurisdiction by law or special expertise with respect to any environmental impact involved, including the environmental impacts of reasonable alternatives to the oil shale leasing program.

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